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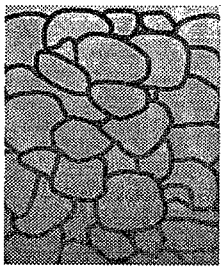
U.S. Environmental Protection Agency

Office of Solid Waste and Emergency Response

Office of Research and Development

BIOREMEDIATION IN THE FIELD

An information update on applying bioremediation to site cleanup.



Update on the Bioremediation Field Initiative

The Bioremediation Field Initiative was established to provide U.S. Environmental Protection Agency (EPA) and state project managers, consulting engineers, and industry with timely information regarding new developments in the application of bioremediation at hazardous waste sites. The Initiative provides evaluation of the performance of selected full-scale field applications, provides technical assistance to remedial project managers (RPMs) and on-scene coordinators (OSCs) through the Technical Support Centers; and is developing a database on the field applications of bioremediation, which is summarized in this bulletin (see p. 12).

Nine sites have been selected for field evaluation of bioremediation: West KL Avenue Landfill Superfund site, Kalamazoo, Michigan; Libby Ground Water Superfund site, Libby, Montana; Park City Pipeline, Park City, Kansas; Bendix Corporation/Allied Automotive Superfund site, St. Joseph, Michigan; Eielson Air Force Base Superfund site, Alaska; Hill Air Force Base Superfund site, Utah; Escambia Wood Preserving site–Brookhaven, Brookhaven, Mississippi; Public Service Company, Denver, Colorado; and Reilly Tar and Chemical Corporation Superfund site, St. Louis Park, Minnesota. Recent results from most of these sites are summarized in this article.

(Continued on page 9)

In This Issue

Libby Site Evaluation Demonstrates Success of Three Biotreatment Approaches for Wood Preserving Wastes

Researchers from Utah State University (USU) and EPA's Robert S. Kerr Environmental Research Laboratory (RSKERL) are in the final stages of evaluating the performance of bioremediation at the Libby Ground Water Superfund site in Libby, Montana. The evaluation, now in its third year, is one of nine bioremediation performance evaluations being sponsored by the Bioremediation Field Initiative (see Update article also on this page). Results indicate that the biological technologies being implemented are effectively degrading the wood preserving contaminants present at the site.

The Libby project is a complex cleanup effort targeting polycyclic aromatic hydrocarbons (PAHs) and pentachlorophenol (PCP) in surface soil, ground water, and nonaqueous phase liquids (NAPLs). Champion International Corporation, which currently runs a lumber mill at the site, operates the bioremediation system which involves a treatment train approach with three separate biological technologies to address the multiphase contamination. Surface soil is being treated in lined, prepared-bed land treatment units (LTUs); extracted ground water from the upper aquifer is being treated in aboveground fixed-film bioreactors; and an in situ bioremediation system is being used to treat contaminants in the upper aquifer. Figure 1 (see p. 5) is a plan view of the site, showing the three treatment areas.

Land Treatment Units

The LTUs are used for bioremediation of contaminated soil from three primary sources: the tank farm, butt dip, and waste pit areas. At the beginning of the project, contaminated soil from these areas was excavated and consolidated in the waste pit area, where the soil was derocked and pretreated. After pretreatment, the contaminated soil was applied in 9-in. lifts to two adjacent, 1-acre, prepared-bed LTUs. Each LTU includes a treatment zone, liner system, and leachate collection system.

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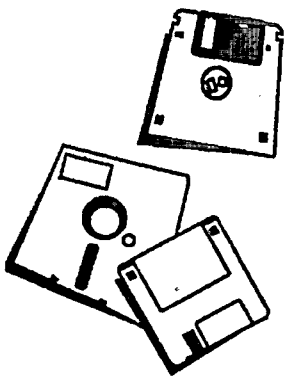

Bioremediation in the Field Search System (BFSS) Available on EPA Bulletin Boards

The Bioremediation Field Initiative is pleased to announce the release of Version 1.0 of the Bioremediation in the Field Search System (BFSS), a new information-sharing resource for bioremediation professionals. BFSS, which was released on major EPA bulletin boards in August, is a PC-based software application that provides access to a database of information on sites across the country where bioremediation is being tested or implemented, or has been completed. For each site, the database contains information on the site location, media and contaminants being treated, treatment technologies being used, the status of treatment operations, and the costs and performance of particular technologies.

BFSS allows the user to search for sites based on location, regulatory authority for cleanup, media, contaminants, status of the project, and treatment used. Based on the search criteria specified by the user, BFSS generates a list of qualifying sites. BFSS then allows the user to view on-line information about these sites and to print reports of information contained in the database.

The Initiative established the BFSS database to provide federal and state project managers, consulting engineers, industry personnel, and researchers with timely information on new developments in field applications of bioremediation. The database currently contains information on more than 160 bioremediation sites, primarily with federal leads. This summer the Initiative is expanding the database by soliciting information from industry, contractors, and vendors—an effort that is expected to double or triple the number of sites in the database. (This solicitation is in accordance with 5 CFR 1320, OMB #2080-0048, approved through April 30, 1997.)

To solicit information on new sites, questionnaires have been sent to hundreds of individuals from EPA regional offices, state environmental agencies, private industry, engineering contractors, and technology vendors. Questionnaires received so far are undergoing a data-quality review. Data on the new sites will appear in upcoming issues of *Bioremediation in the Field*, and will be available in Version 2.0 of BFSS, tentatively scheduled for release early in 1995. If you would like to provide information on a bioremediation site for inclusion in the BFSS database, please call Ann Tran of Eastern Research Group, Inc., at 617-674-7303.

Bioremediation Field Initiative Contacts

Fran Kremer, Ph.D.
Coordinator, Bioremediation Field Initiative
U.S. Environmental Protection Agency
Office of Research and Development
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7346

Michael Forlini
U.S. Environmental Protection Agency
5102W
Technology Innovation Office
Office of Solid Waste and Emergency Response
401 M Street, SW
Washington, DC 20460
703-308-8825

To be added to the mailing list to receive *Bioremediation in the Field*, call 513-569-7562.

The Bioremediation Field Initiative is a cooperative effort among the Technology Innovation Office (TIO) of the Office of Solid Waste and Emergency Response (OSWER) and the Office of Science, Planning, and Regulatory Evaluation (OSPRE) and Office of Environmental Engineering and Technology Demonstration (OEETD) of the Office of Research and Development (ORD). Major contributors to the Initiative include the waste programs in the EPA regional offices; the following laboratories in ORD: Ada, OK; Athens, GA; Cincinnati, OH; Gulf Breeze, FL; and Research Triangle Park, NC; the U.S. Air Force; state agencies; industry; and universities.

BFSS will be available on the Alternative Treatment Technology Information Clearinghouse (ATTIC) (703-908-2138), Cleanup Information (CLU-IN) (301-589-8366), and Office of Research and Development (ORD) (513-569-7610) bulletin board systems. The software is designed to be downloaded and operated off of a hard disk or a local area network (LAN), not to be operated remotely from a bulletin board. BFSS also will be available on diskette from the Center for Environmental Research Information (CERI) by calling 513-569-7562. Information in the database will continue to be summarized in the "Field Applications of Bioremediation" table, a regular feature of EPA's *Bioremediation in the Field* bulletin (see p. 12).

Updated Data Reveal Bioremediation Trends

According to the recently updated data, soil is the most common medium undergoing bioremediation, present at 124 sites in the BFSS database. Ground water is second, present at 63 sites, followed by sediments at 23, sludge at 10, and surface water at 2 (see Figure 1).

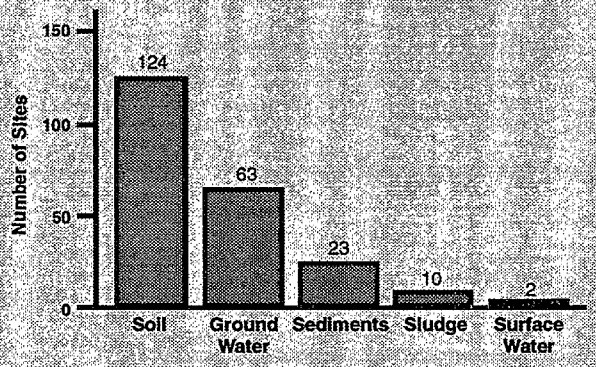

Figure 1. Number of sites treating each media type.

Among the contaminants being treated or considered for treatment at sites in the database, petroleum is a predominant contaminant at 63 sites, followed by wood preserving wastes at 35, solvent wastes at 27, and herbicides/pesticides at 15. Thirty sites in the database list other wastes, such as munitions and polychlorinated biphenyls (PCBs), as predominant contaminants undergoing treatment (see Figure 2).

In situ treatment technologies are selected more often than ex situ technologies to treat contaminants. In situ techniques are being considered for use or implemented at 72 out of 159 sites in the database. In situ ground-water treatment and in situ soil treatment are most common (each at 16 percent), followed by bioventing (14 percent), air sparging (4 percent), in situ sediment (4 percent), and confined land treatment (1 percent). Ex situ nonreactor treatment technologies (aerated lagoon, land treatment, and pile treatment or composting) are used at 63 out of 159 sites, and ex situ reactor treatment technologies are used at 38 out of 159 sites (see Figure 3.).

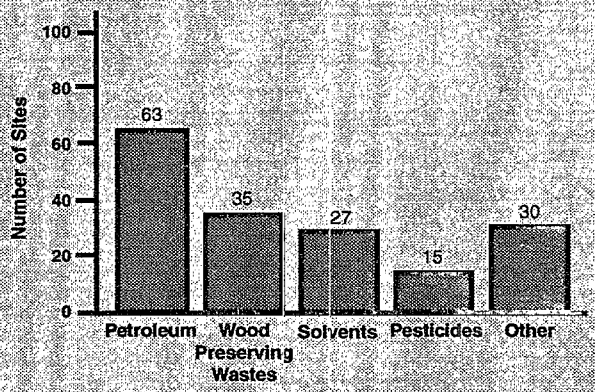

Figure 2. Breakdown of sites by type of contamination.

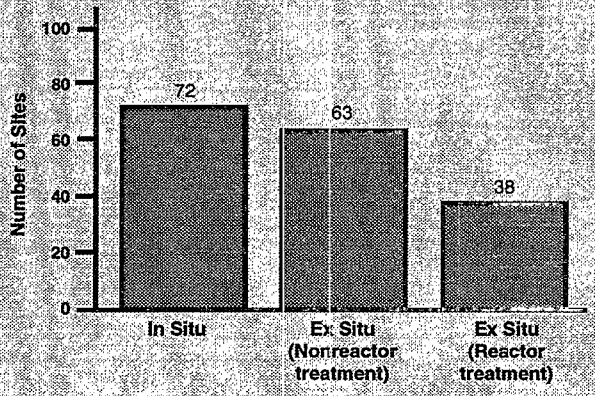

Figure 3. Breakdown of sites by treatment technology.

Fixed-Film Bioreactor Implemented at Former Silver Smelting Site

A fixed-film bioreactor treatment system is effectively treating ground water contaminated with ketones, phenols, and toluene at the Silvex Corporation site in St. Augustine, Florida. The system was developed as an interim remedial design by the Florida Department of Environmental Protection (FDEP) to reduce the potential for migration of contaminated ground water from the site into nearby Ward's Creek.

Prior to 1980, the site was used by the Silvex Corporation for a silver smelting operation that recovered metals from waste X-ray films. The operation used fuel from the Naval Air Station in Jacksonville, Florida. In 1981, as a result of vandalism at the site, waste fuel containing spent paint, solvents, and cold carbon degreasers was spilled from a 25,000 gallon storage tank onto the ground, contaminating ground water beneath the tank.

Investigations conducted by FDEP in 1985 indicated that the surficial aquifer in the spill area and the area hydrologically downgradient of the spill contained elevated levels of ketones (acetone, methyl ethyl ketone, and methyl isobutyl ketone), phenols, and toluene. A risk assessment subsequently was performed to determine cleanup goals. Ground-water goals were based on EPA/FDEP standards, reference doses, and carcinogenicity.

After the initial investigation, a feasibility study was conducted to evaluate the technical feasibility and cost effectiveness of various treatment technologies, including air stripping, carbon adsorption, steam stripping, and submerged fixed-film bioreactor treatment. Based on the results of this study, which indicated the presence of ketones in excess of 200 mg/L, air stripping and carbon adsorption were determined to be technically infeasible. A submerged fixed-film bioreactor was selected as the most appropriate treatment alternative.

In 1992, FDEP performed a bench-scale study to evaluate the effectiveness of the proposed submerged fixed-film bioremediation system. The study, which was conducted using polypropylene beads in glass cells at four different residence times, showed a removal efficiency of 50 to 99 percent for ketones through both biodegradation and volatilization, and a 50 percent removal efficiency for phenols through biodegradation alone.

Following the bench-scale study, an onsite pilot-scale study was conducted to provide information for the design of a full-scale system. Contaminant removal was evaluated at flow rates of 0.5, 1, and 2 gallons per minute (gpm) in a three-stage pilot-scale bioreactor. An onsite gas chromatograph was used to monitor influent and effluent ketone concentrations on a daily basis. Results from the study demonstrated a contaminant removal efficiency of greater than 99 percent for the pilot-scale reactor.

In 1993, FDEP used the data obtained from the pilot-scale study, along with information about the distribution of the existing ground-water plume, to design and install a four-stage bioreactor capable of treating up to 18 gpm. A two-stage granular activated carbon polishing unit also was incorporated. In order to acclimate the system, the bioreactor was filled with contaminated water. Activated sludge from a local treatment plant was added and the bioreactor was aerated for 3 days.

Data from the site indicate that the reactor is meeting effluent discharge criteria (see Table 1). Daily onsite operation and maintenance is being conducted, and telemetry is being used for remote monitoring of system performance.

For more information, contact George Heuler of FDEP at 904-488-0190.

Table 1. Summary of Analytical Results[a]

Contaminant	Bioreactor Influent	Bioreactor Effluent	GAC Effluent	Effluent Cleanup Criteria
Acetone	11,000	11	34	700
Methyl Ethyl Ketone	41,000	<10	<10	170
Methyl Isobutyl Ketone	16,000	36	<10	350
Phenol	1,200	<10	<10	20
2,4-Dimethylphenol	1,200	<10	<10	400
2-Methylphenol	1,500	<10	<10	350
4-Methylphenol	3,000	<10	<10	350
BOD_5 (mg/L)	1,400	68	NA[b]	NA
COD (mg/L)	1,700	160	NA	NA

[a]All values are expressed in g/L unless otherwise specified.

[b]NA = data not available.

EPA and Industry Sign CRADA To Develop Innovative "Lasagna" Process

On January 27, 1994, EPA Administrator Carol Browner signed a Cooperative Research and Development Agreement (CRADA) to help develop and field test the "lasagna" process—an innovative combination of technologies designed to remediate hazardous wastes in low-permeability soils. The CRADA links the specific technological innovations and research capabilities of industry's Lasagna Technology Consortium (LTC), formed by Dupont, General Electric, and Monsanto, with those of EPA's Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio. Clean Sites, Inc. is assisting with the coordination of this project as part of the public-private partnership project implemented through a cooperative agreement with EPA's Technology Innovation Office. Through the CRADA, RREL and members of LTC will work jointly to develop the lasagna process, so named because it involves a number of layered subsurface electrodes and treatment zones.

The lasagna process first came to EPA's attention through the Remediation Technologies Development Forum (RTDF), a consortium of public and private interests dedicated to identifying and solving specific hazardous waste remediation problems (see article in Issue No. 10 of *Bioremediation in the Field*). One of the primary problems targeted by RTDF has been remediation of hard-to-treat wastes in low-permeability, silt- and clay-laden soils. The lasagna process was proposed by Monsanto Company as a potentially cost-effective cleanup technique for such soils.

Although the lasagna process involves sophisticated technologies, the basic treatment concept is relatively simple. A low-voltage electric current is applied to soil by subsurface electrodes. This current stimulates a dynamic flow of contaminants through the low-permeability material into high-permeability treatment zones, where the contaminants are treated. Figure 1 illustrates a possible configuration for the lasagna process, showing the electrodes, contaminated soil, and treatment zones.

The electrical component of the lasagna process involves a phenomenon known as *electroosmosis*, which is the movement of pore fluid in soils under an electric current. Most soil particles, including clays, carry a negative surface charge. As a result, soil particles immersed in an electrolyte such as ground water attract positively charged ions, creating a double layer with a net positive charge at the surface of each particle. When a current is applied to a section of saturated soil, the ions and associated fluid in the charged double layer move toward the cathode. The remainder of the pore fluid, which contains soil contaminants, moves in the same direction as the double-layer fluid due to viscous interactions. This net flow of pore fluid toward the cathode is called electroosmosis. Because the rate of electroosmosis does not depend on the size of the soil particles, the process is just as effective in low-permeability clay soils as in high-permeability sandy soils.

The high-permeability treatment zones used in the lasagna process are created with techniques such as hydrofracturing, directional drilling, and sheet piling, which originally were developed by the petroleum industry. In hydrofracturing, for example, a slurry is injected into soil to create horizontal, pancake-shaped porous zones up to 30 ft in diameter. (Researchers also are considering using hydrofracturing to inject conductive carbon into the soil to act as horizontal electrodes.) The treatment zones are situated between the electrodes to intercept contaminants as they migrate under the applied current. Because electroosmotic

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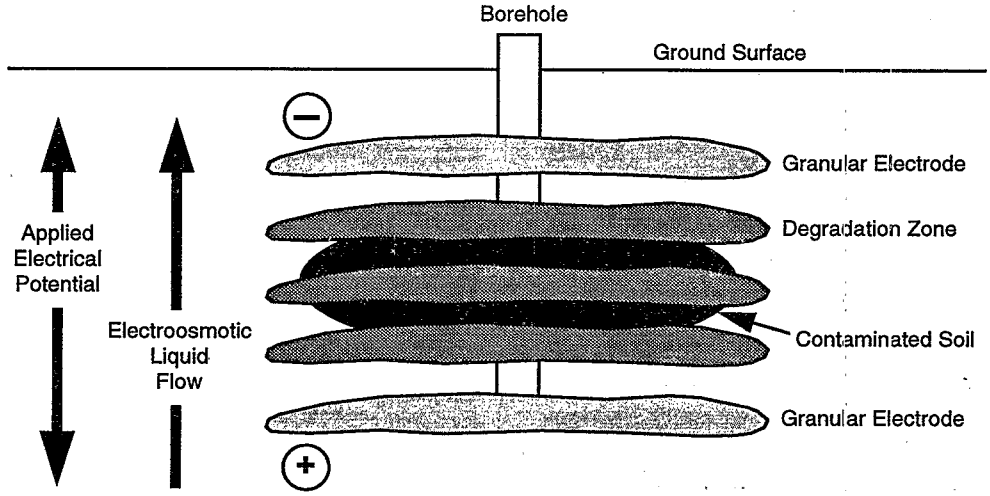


Figure 1. A possible configuration for the lasagna process.

Libby Site Evaluation Demonstrates Success of Treatment Train Approach

(Continued from page 1)

Currently, effluent from the reactors also infiltrates the subsurface and migrates through the waste pit area. This allows recycling and amending of any available nutrients and reoxygenation of the water.

Researchers evaluated the performance of the LTUs by sampling the soil in each lift in each LTU. The primary purpose of the sampling was to determine the statistical significance and extent of PAH and PCP degradation as a function of time and depth within each LTU. Sampling procedures were designed to minimize sample variance and provide representative information about the transformation of PAHs and PCP. The LTUs were sampled in May, June, July, and September 1991, and in September 1992, representing the top lifts and those previously treated. Laboratory mass-balance investigations of radiolabeled compounds, which demonstrate the mineralization and humification potential of target contaminants, were used to corroborate the results of field sampling.

In total, more than 300 soil samples were collected from the LTUs and analyzed for PAH compounds using gas chromatography/mass spectrometry (GC/MS) and for PCP using a GC/electron capture detector (ECD). These analyses indicated that land treatment reduced the mean concentration of almost every target contaminant to below the cleanup level goals, with two exceptions, for which the mean concentrations were only slightly higher than the target levels. The laboratory evaluation of soil microbial metabolic potential demonstrated that two indicator compounds, PCP and phenanthrene, could be mineralized by microorganisms present in the contaminated soil under the temperature and moisture conditions present at the site. These tests also showed that PCP and phenanthrene would be unlikely to volatilize under prevailing site conditions, suggesting that the removal of PCP and PAHs from the LTUs occurred because of biological processes rather than physical/chemical processes.

Aboveground Fixed-Film Bioreactor Treatment

The aboveground treatment unit, which has been operating since February 1990, is designed to remove PAHs and PCP from extracted ground water. The unit consists of an equalization tank with two fixed-film bioreactors operated in series. The first reactor provides rough treatment; the second reactor polishes and reoxygenates the effluent prior to reinjection through an infiltration trench. PAH removal occurs primarily in the first reactor; PCP removal is balanced equally between the reactors.

Bioreactor sampling conducted in 1991 and 1992 provided various chemical, physical, and biological parameters to assess the system's effectiveness for removing PAHs and PCP from ground water. In addition, a pilot-scale reactor was constructed and operated to estimate the fate of chemicals within the bioreactors.

The fixed-film bioreactor system was able to remove PCP (80 percent) and PAHs (90 percent) at a flow rate of 10 gpm. When the flow rate was increased to 15 gpm, the removal rate efficiency decreased. This decrease has been attributed to both the decrease in hydraulic retention time (HRT) and the increased organic loading. At a flow rate of 10 gpm, the HRT was 30 hours and the effluent concentrations of PCP and PAHs were 0.3 to 0.9 mg/L and less than detection limit, respectively. When the flow rate was increased to 15 gpm, the HRT was 20 hours, and the effluent concentrations of PCP and PAHs were 6 to 12 mg/L and 0.6 to 6 mg/L, respectively. Sampling indicated that the PAH and PCP influent concentrations were highly variable with approximate log normal distribution. The organic loading at 15 gpm was higher than at 10 gpm by a factor of 3 to 4. The removal rate of PCP and PAHs with two rings or more was affected the most, while naphthalene removal was affected the least.

In Situ Bioremediation

During the period of the performance evaluation, hydrogen peroxide and inorganic nutrients were injected into the upper aquifer to stimulate the growth of contaminant-specific microbes. (Compressed oxygen gas has since been substituted for hydrogen peroxide in the in situ bioremediation system.) Hydrogen peroxide was injected at a flow rate of approximately 100 gpm through three injection clusters, resulting in a concentration of approximately 100 mg/L of hydrogen peroxide. Inorganic nutrients in the form of potassium tripolyphosphate and ammonium chloride were continuously added to achieve concentrations in the injection water of 2.4 mg/L nitrogen and 1 mg/L phosphorus.

The evaluation of the in situ bioremediation system focused on characterizing ground water, solid aquifer material, and NAPL associated with the solid aquifer material. The aquifer was sampled during 1991 and 1992. Ground water was analyzed for concentrations of dissolved oxygen, PAHs and PCP, and iron and manganese. (Iron and manganese are indicators of the aquifer's potential abiotic demand for injected hydrogen peroxide.) Solid aquifer material was analyzed for PAH and PCP concentrations in treated and background areas. Laboratory mass-balance experiments using radiolabeled target compounds were used to provide additional information concerning biotic reactions (i.e., mineralization) and potential abiotic reactions (i.e., contaminant removal from poisoned controls).

Concentrations of PAHs and PCP in ground water were found to be lower in wells considered to be under the influence of the injection system than in wells considered to be outside the influence of the injection system. Concentrations of iron and manganese in ground water were found to be inversely proportional

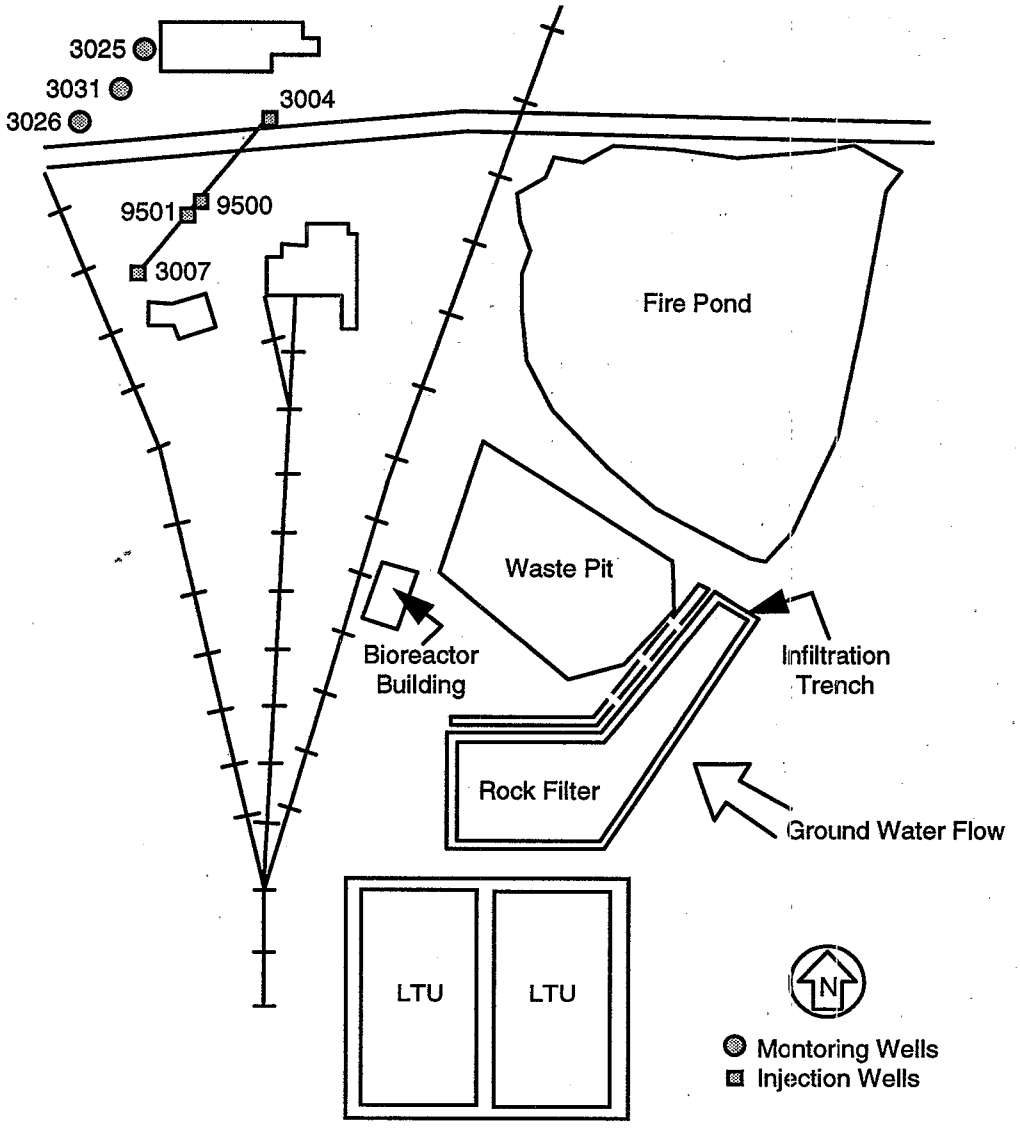


Figure 1. Plan view of the Libby site, showing the three treatment areas.

to concentrations of dissolved oxygen, suggesting that these inorganic compounds might exert a demand on oxygen supplied by hydrogen peroxide and might limit the oxygen intended for aquifer microorganisms. Contaminant concentrations in the solid aquifer material were found to range from 5 mg/kg to 687 mg/kg for total PAHs, and 70 mg/kg to 2,525 mg/kg for total petroleum hydrocarbons. The highest concentrations of contaminants in the aquifer were found in the NAPL, which contained greater than 10,000 mg/L PAHs and greater than 1,000 mg/L PCP. Mass-balance studies demonstrated that phenanthrene was mineralized by microbes indigenous to the site, and that up to 70 percent of the radiolabeled carbon became incorporated into the aquifer matrix. No mineralization was observed in the poisoned controls.

The evaluation of in situ bioremediation suggests that degradation of contaminants in ground water is easier than bioremediation of contaminants associated with the solid or NAPL phases, because of limitations on mass transport of oxygen and nutrients from ground water to the solid and NAPL phases. A common concern is that the residual NAPL contaminants might contribute to further ground-water contamination at the Libby site.

Performance Evaluation Reports

Separate reports are being prepared for each of the three biological treatment systems at the site. Information generated from full-scale characterization and monitoring, pilot studies, and laboratory treatability studies was combined with other site data to provide an integrated evaluation of bioremediation performance. EPA intends for the results of the evaluation to be used to evaluate and select rational approaches for characterization, implementation, and monitoring of bioremediation at other sites.

For more information, contact Scott Huling of RSKERL at 405-436-8610 or John Matthews of RSKERL at 405-436-8600. Copies of site reports will be published later this year. See future issues of the bulletin for notices of their availability.

EPA and Industry Sign CRADA To Develop Innovative "Lasagna" Process

(Continued from page 5)

migration is relatively slow (approximately 1 in. per day), the treatment zones are spaced close together to minimize the distance that contaminants must be transported.

The most effective treatment for contaminants once they reach the treatment zones is under investigation. LTC and RREL currently are considering both physical/chemical and biological methods. In one biological treatment under consideration, activated carbon would be used to sorb organic contaminants, which then would be degraded by microorganisms. Because the treatment zones are porous, they could easily be infused with amendments, such as nutrients, to enhance biotreatment. These amendments also could be delivered to the soil adjacent to the treatment zones by electroosmotic migration.

The three companies in the LTC have agreed to demonstrate the feasibility of the lasagna concept at a site contaminated with trichloroethylene in Paducah, Kentucky. RREL will conduct studies on hydraulic fracturing to investigate installation of horizontal subsurface electrodes and treatment zones. RREL also will examine the potential for bioremediation under the conditions expected in the lasagna process. Both RREL and LTC believe that the lasagna process will offer a cost-effective alternative to other technologies currently available for treatment of low-permeability contaminated soils.

For more information, contact Leland Vane of RREL at 513-569-7799.

Research on Anaerobic Bioremediation of BTEX Conducted at Naval Weapons Station Seal Beach

The Naval Facilities Engineering Service Center (NFESC) in Port Hueneme, California, has conducted a field study on the anaerobic degradation of BTEX compounds in ground water at an unleaded fuel spill site. The study, which took place at Naval Weapons Station Seal Beach in Seal Beach, California, was part of a 4-year research project sponsored by the Naval Facilities Engineering Command (NFEC) in Washington, DC, and the Southwest Division of NFEC in San Diego, California.

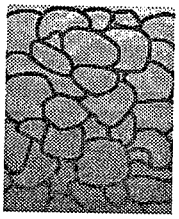
Prior to the field study, laboratory studies were conducted in sealed, anaerobically maintained microcosms using soil and ground water from the Seal Beach site. The microcosms were amended with different nutrients, carbon sources, and electron acceptors. In these studies, anaerobic microbial populations were found to degrade benzene, toluene, ethylbenzene, *m*-xylene, and *p*-xylene. It was unclear whether degradation of *o*-xylene occurred. All of the compounds that were removed degraded under sulfate-reducing conditions, except ethylbenzene, which degraded only under nitrate-reducing conditions.

The field study was conducted using three bioreactors, each consisting of a sealed, stainless-steel column (0.3 m x 1.2 m) filled with contaminated soil and inserted into the ground at the site so that its top was flush with the soil surface. In the first column, contaminated ground water from the site was pumped from the bottom of the column up through the soil. The pumping maintained sulfate-reducing conditions in the column, because ground water at the site contains naturally high levels of sulfate (approximately 80 mg/L). In the second column, nitrate-amended ground water was pumped up from the bottom of the column. The third column was used as a static control. Ground-water samples were collected periodically from six sideports evenly spaced up the side of each column to measure hydrocarbon concentrations in the water as they moved up toward the soil surface.

Anaerobic degradation of toluene, *m*-xylene, and *p*-xylene was observed in the unamended and static control columns, which were presumed to be under sulfate-reducing conditions. In these columns, contaminant levels measured at the sideports closest to the bottom were very low, suggesting that complete biodegradation of contaminants occurred in the first few inches of soil. Degradation of toluene, ethylbenzene, *m*-xylene, and *p*-xylene was observed in the column amended with nitrate. In general, contaminant removal was greater in the nitrate-amended column than in the nonamended columns.

The results of the laboratory- and pilot-scale studies conducted on soil and ground water from Naval Weapons Station Seal Beach indicate that a combination of electron acceptors is involved in the anaerobic degradation of BTEX compounds. Bioremediation with multiple electron acceptors could be a means of accelerating anaerobic degradation of some BTEX compounds and a way of initiating bioremediation of others. By determining the most effective combination of electron acceptors, researchers might be able to identify a way to practicably remediate aromatic hydrocarbons in anaerobic settings.

For more information, contact Carmen Lebron of NFESC at 805-982-1616.



Update on the Bioremediation Field Initiative

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At the **Libby Ground Water Superfund site**, all field evaluation sampling has been completed. Separate reports are being prepared on each of the three treatment processes under evaluation. For details, see the article on p. 1 of this bulletin.

The retrospective evaluation of bioremediation at the **Public Service Company site** has been completed. The Bioremediation Field Initiative currently is preparing a report that summarizes the results of aquifer core sampling and ground-water flow modeling and proposes several principles for assessing in situ bioremediation. The report is scheduled to be available this summer, and a notice of its release will appear in a future issue of this bulletin.

The bioventing field study at **Eielsen Air Force Base** (AFB), Alaska, is concluding this summer, with final soil sampling planned for July 1994. The project objectives are to document the feasibility of bioventing of petroleum hydrocarbons (JP-4 jet fuel) in cold climates in conjunction with various low-cost soil warming methods to increase the rate of biological activity. Based on almost 3 years of data, "active warming" (application of warm water at a low rate) and "surface warming" (heat input from shallow buried heat tape) performed very well, providing year round summer-like temperatures throughout the contaminated soil zone from 2 to 7 ft below grade. The "passively warmed" plot, which was heated by solar warming in the summer enhanced with clear plastic on the surface, did not perform significantly differently than the unheated control. Results from the final soil sampling will be used to calculate the amount of petroleum removed per unit cost of heating.

Nearing the end of the 3 ½ year study begun in December 1990, the objective of the bioventing project at **Hill AFB** is to document bioventing of petroleum hydrocarbons (JP-4 jet fuel) in a very large vadose zone. Contamination exists from 10 to 95 ft below grade. Measurements of soil gas and in situ respiration tests have revealed that the air injection system is operating (1) by providing oxygen to all of the contaminated soil, near the air injection well, thereby inducing biodegradation of the fuel; and (2) by transporting vapor phase petroleum away from the contaminated area into the surrounding uncontaminated soil, where these clean soils act as a huge biofilter destroying the organic vapors as they travel. Using the surrounding clean soil as an in situ biofilter increases the effective size of the biologically active zone by a factor of 10. Final soil sampling in summer 1994 will indicate total petroleum removal over the length of the study.

The bioventing study is continuing at the **Reilly Tar and Chemical Corporation site**, an abandoned wood-preserving facility contaminated with creosote. This demonstration is evaluating the potential of bioventing to remediate soils contaminated with polycyclic aromatic hydrocarbons (PAHs). The pilot field study features active venting and monitoring of a "treatment area" and monitoring of a "no treatment control area." These two areas are 50 ft by 50 ft. After 18 months of bioventing (as of June 1994), respiration rates are ranging from detectable to more than 0.9 percent O_2 per hour. Current measured respiration rates are consistent with a 20 percent reduction in PAH contamination per year, or twice the target rate of 10 percent per year.

A demonstration of in situ bioremediation at the **Park City Pipeline, Park City**, Kansas, site using nitrate as an electron acceptor showed that biodegradation accounted for removal of more than 95 percent of toluene and ethylbenzene from ground water at the site, and from 68 to 76 percent of xylenes. More than 90 percent of benzene was removed, but most of the removal was accounted for by flushing.

Work is continuing at the **Bendix/Allied Signal site** in St. Joseph, Michigan, to evaluate the impact of the plume in the confining area under Lake Michigan. The bed of the lake will be sampled and microcosms will be set up to assess the influence of the aerobic portion of the plume interfaced with the anaerobic sediment.

EPA Publishes Educational Booklet on Bioremediation

EPA recently published *Bioremediation: Innovative Pollution Treatment Technology*, a 20-page booklet describing bioremediation in easy-to-understand terms. The publication also highlights the research and engineering activities of EPA's Office of Research and Development (ORD) aimed at advancing the understanding, development, and field evaluation of bioremediation. The booklet is intended to provide the non-technical reader with a general understanding of bioremediation and its application to both hazardous waste sites and oil spills.

EPA anticipates that the booklet will be useful as an educational resource to a wide range of audiences, including federal, state, and local environmental decision-makers; environmental organizations; colleges and universities; international environmental ministries; and interested citizens. To order the booklet, mail or fax a request to ORD Publications, U.S. Environmental Protection Agency, 26 West Martin Luther King Drive, Cincinnati, OH 45268 (fax: 513-569-7566); or call 513-569-7562. When ordering, reference the EPA publication number: EPA/640/K-93/002.

Update on the RTDF Bioremediation Work Group

The Remediation Technologies Development Forum's (RTDF) Bioremediation Work Group is in the process of gathering and analyzing site characterization data for cometabolic bioventing, natural attenuation, and accelerated anaerobic degradation. A treatability study at the Dover Air Force Base (AFB), Delaware, indicated that accelerated anaerobic degradation is appropriate for treating ground water contaminated with trichloroethene at the site. Cometabolic bioventing and natural attenuation might be appropriate for other contamination at the site. At Wurtsmith AFB, Michigan, two potential test sites for natural attenuation and cometabolic bioventing have been identified. The Work Group plans to initiate four bioremediation projects in fiscal year 1994: one accelerated anaerobic degradation project at Dover AFB, one cometabolic bioventing project at Wurtsmith AFB, and two natural attenuation studies at different sites at Wurtsmith AFB. The Work Group plans to phase in additional projects over the next several years, increasing the number of projects to seven: two accelerated anaerobic degradation, two cometabolic bioventing, and three natural attenuation studies.

The industrial members of the Work Group are finalizing an agreement that will form the Bioremediation Research Consortium. This agreement describes the planned research projects along with their schedules and milestones, and the responsibilities of each participant. EPA is developing a Cooperative Research and Development Agreement (CRADA), which will allow the Agency to work with the Consortium on planned collaborative efforts. The Department of Energy (DOE) plans to sign a Memorandum of Understanding with the Consortium; and the Air Force is proposing to sign a CRADA with the Consortium. EPA, the Department of Defense (DOD), DOE, and the Consortium members will perform the necessary laboratory research, field studies, and modeling to better understand, develop, and scientifically validate the three biological processes for degrading chlorinated solvents. The federal and industrial participants will provide the necessary resources to accomplish the planned research efforts. Both the Air Force and DOE are working with the Bioremediation Work Group to prepare a proposal to be submitted under the Strategic Environmental Research and Development Program to fund the field and analytical work at the test sites.

Back issues of *Bioremediation in the Field* can be ordered from EPA by calling 513-569-7562 and from NTIS by calling 800-553-6847. When ordering, please specify the issue and publication number.

Issue #	*Publication #*	*Issue #*	*Publication #*	*Issue #*	*Publication #*
1	NTIS PB91-228023	5	NTIS PB93-126175	9	EPA/540/N-93/002
2	EPA/540/2-91/007 *(out of stock)*	6	EPA/540/N-92/002 *(out of stock)*	10	EPA/540/N-94/500
3	NTIS PB92-224807	7	EPA/540/N-92/004	11	EPA/540/N-94/501
4	NTIS PB92-224708	8	EPA/540/N-93/001		

EPA Bioremediation Publications

To order EPA documents, call 513-569-7562 or write to ORD Publications, U.S. Environmental Protection Agency, 26 West Martin Luther King Drive, Cincinnati, OH 45268. To order NTIS documents, call 800-553-6847 or write to National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Emerging Technology Summary: Pilot-Scale Demonstration of a Two-Stage Methanotrophic Bioreactor for Biodegradation of Trichloroethene in Ground Water..... **EPA/540/S-93/505**

Summary Paper: In Situ Bioremediation of Contaminated Vadose Zone Soil **EPA/540/S-93/502**

Engineering Issue: In Situ Bioremediation of Contaminated Unsaturated Subsurface Soils..... **EPA/540/S-93/501**

Handbook for Constructed Wetlands Receiving Acid Mine Drainage..... **NTIS PB93-233914AS**

SITE Emerging Technologies: Bioscrubber for Removing Hazardous Organic Emissions from Soil, Water, and Air Decontamination Processes..... **NTIS PB93-227205**

Guide for Conducting Treatability Studies under CERCLA: Biodegradation Remedy Selection— Interim Guidance **EPA/540/R-93/519a**

Guide for Conducting Treatability Studies under CERCLA: Biodegradation Remedy Selection— Quick Reference Fact Sheet..... **EPA/540/R-93/519b**

Symposium on Bioremediation of Hazardous Wastes: Research, Development, and Field Applications..... **EPA/600/R-93/054**

Bioremediation Case Study Collection: 1991 Augmentation of the Alternative Treatment Technology Information Center (ATTIC) **EPA/600/R-92/043**

Characterizing Heterogeneous Wastes ..... **NTIS PB92-216894**

Fundamentals of Ground-Water Modeling ..... **NTIS PB92-232354**

A Study to Determine the Feasibility of Using a Ground Penetrating Radar..... **NTIS PB92-169382**

Bioremediation of Hazardous Waste..... **EPA/600/R-92/126**

Methodologies for Evaluating In Situ Bioremediation of Chlorinated Solvents ..... **NTIS PB92-146943**

TCE Removal from Contaminated Soil and Ground Water ..... **NTIS PB92-224104**

In Situ Bioremediation of Contaminated Ground Water ..... **NTIS PB92-224336**

Technology Evaluation Report: Biological Treatment of Wood Preserving Site Ground Water by Biotrol, Inc..... **NTIS PB92-110048**

Applications Analysis Report: Biological Treatment of Wood Preserving Site Ground Water by Biotrol, Inc..... **NTIS PB91-227983**

Microbial Removal of Halogenated Methanes, Ethanes, and Ethylenes in an Aerobic Soil Exposed to Methane (Journal Version)..... **NTIS PB89-103196**

Sequential Reductive Dehalogenation of Chloranilines by Microorganisms from a Methanogenic Aquifer ... **NTIS PB90-117219**

Creosote-Contaminated Sites ..... **NTIS PB90-129552**

Action of a Fluoranthene-Utilizing Bacterial Community on Polycyclic Aromatic Hydrocarbon Components of Creosote..... **NTIS PB90-245721**

Assessing Detoxification and Degradation of Wood Preserving and Petroleum Wastes in Contaminated Soil..... **NTIS PB90-245275**

Alaskan Oil Spill Bioremediation Project..... **NTIS PB90-216466**

Laboratory Studies Evaluating the Enhanced Biodegradation of Weathered Crude Oil Components through the Application of Nutrients..... **NTIS PB90-264011**

Total Organic Carbon Determinations in Natural and Contaminated Aquifer Materials ..... **NTIS PB91-129205**

Anaerobic In Situ Treatment of Chlorinated Ethenes..... **NTIS PB91-137067**

In Situ Bioremediation of Spills from Underground Storage Tanks: New Approaches for Site Characterization, Project Design, and Evaluation of Performance..... **NTIS PB89-219976**

Comparison of Methods to Determine Oxygen Demand for Bioremediation of a Fuel-Contaminated Aquifer..... **NTIS PB89-207351**

Available Models for Estimating Emissions Resulting from Bioremediation Processes: A Review..... **NTIS PB90-228610**

Role of Microorganisms in the Bioremediation of the Oil Spill in Prince William Sound, Alaska ..... **NTIS PB90-263070**

Approach to Bioremediation of Contaminated Soil ..... **NTIS PB91-116152**

Protocol for Testing Bioremediation Products against Weathered Alaskan Crude Oil..... **NTIS PB91-137018**

Reductive Dehalogenation: A Subsurface Bioremediation Process..... **NTIS PB91-144873**

Field Evaluation of In Situ Biodegradation for Aquifer Restoration..... **NTIS PB88-130257**

Alternative Biological Treatment Processes for Remediation of Creosote-Contaminated Materials: Bench-Scale Treatability Studies..... **NTIS PB91-179085**

Nitrate for Biorestoration of an Aquifer Contaminated with Jet Fuel ..... **NTIS PB91-164285**

Movement of Bacteria through Soil and Aquifer Sand..... **NTIS PB91-164277**

Selection of Nutrients to Enhance Biodegradation for the Remediation of Oil Spilled on Beaches..... **NTIS PB91-233304**

Effect of Sodium Chloride on Transport of Bacteria in a Saturated Aquifer Material..... **NTIS PB92-110428**

Oil Spill Cleanup ..... **NTIS PB92-110469**

Enhanced Bioremediation Utilizing Hydrogen Peroxide as a Supplemental Source of Oxygen: A Laboratory and Field Study ..... **NTIS PB90-183435**

Bioremediation of Contaminated Surface Soil.... **NTIS PB90-164047**

Guide for Conducting Treatability Studies under CERCLA, Aerobic Biodegradation Remedy Screenings..... **NTIS PB92-109065**

Interactive Simulation of the Fate of Hazardous Chemicals during Land Treatment of Oily Wastes: Ritz User's Guide..... **NTIS PB88-195540**

Microbial Decomposition of Chlorinated Aromatic Compounds..... **EPA/600/2-86/090**

Removal of Volatile Aliphatic Hydrocarbons in a Soil Bioreactor..... **NTIS PB88-180393**

Transformation of Halogenated Aliphatic Compounds..... **NTIS PB88-170568**

Understanding Bioremediation: A Guidebook for Citizens **EPA/540/2-91/002**

Methods for Monitoring Pump-and-Treat Performance **EPA/600/R-94/123**

FIELD APPLICATIONS OF BIOREMEDIATION[1]

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
I	Baird and McGuire Holbrook, MA CERCLA Fund Lead	David Lederer (617)573-5738 Federal (or national) organization Martin Horne (617)292-5716 State (or provincial) organization	Ground water (BTEX, chlordane, creosote) Volume: 300 gallons per minute % of total vol. at site: 100%	Full-scale remediation has been underway since 01/93. Incurred cost: capital, $13M. Cost per year: O&M, $2M.	Ground water: MCLs.	Ex situ treatment, activated sludge, completely mixed flow. Aerobic conditions, exogenous organisms. Nonbiological technologies: chemical treatment for ground water and incineration for soil.	None.
I	Charles George Landfill Tyngsboro, MA CERCLA Fund Lead	David Dickerson (617)573-5735 Federal (or national) organization Dale Young (617)292-5785 State (or provincial) organization	Ground water (arsenic, benzene)	Predesign.	Ground water: arsenic, 30 µg/L; benzene, 5 µg/L.	Ex situ treatment, activated sludge, completely mixed flow. Aerobic conditions, exogenous organisms. Nonbiological technologies: activated sludge for leachate, preaeration, carbon filtering.	None.
I	Charlestown Navy Yard** Boston, MA CERCLA State Lead	Stephen Carlson (617)242-5680 State (or provincial) organization	Sediments (creosote, PAHs)	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 09/93.	Not established.	In situ treatment, in situ sediment bioremediation. Oxygen source, nutrient addition. Aerobic conditions, indigenous organisms.	Both 30-day and 60-day laboratory scale studies were conducted. They were able to reduce concentrations which varied from 6,000-20,000 ppm according to location, to between 100-300 ppm. Most of the reduction occurred in the first 30 days. The State was looking for target levels of 25 ppm, which were below the background levels of the Boston Harbor, where the site is located. It was not felt that these could be achieved through bioremediation. There is a slow natural process of attenuation taking place, and a minimal environmental risk. The options are now to let this process continue, or to dredge or cap the site.

[1] CERCLA/RCRA/UST sites at which bioremediation activities are being considered, planned, or implemented, or have been completed. This site information has been summarized from the Bioremediation in the Field Search System (BFSS) database (see article on p. 2).

*Indicates a new site.
**Indicates that contacts have provided updated information for this bulletin.

Shading indicates a non-CERCLA site.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
I	Coakley Landfill** North Hampton, NH CERCLA Enforcement Lead	Steve Calder (617)573-9626 Federal (or national) organization Dan Coughlin (617)573-9620 Federal (or national) organization	Ground water (ammonia)	Full-scale remediation is planned. Currently in predesign. Expected start 01/96.	Ground water: NPDES requirements.	In situ treatment, in situ ground water bioremediation. Nonbiological technologies: metal precipitation and air stripping.	None.
I	General Electric** Pittsfield, MA RCRA Lead (Federal)	Joan Blake (202)260-6236 Federal (or national) organization	Sediments (PCBs) Volume: 12 cubic meters	Full-scale bioremediation is not planned. Laboratory-scale and pilot-scale studies are being conducted.	Sediments: PCBs, 2 ppm (performance-based).	Ex situ treatment, sequencing batch reactor, batch flow. Anaerobic conditions, indigenous organisms. Nonbiological technologies: incineration, flotation separation.	Bioremediation of PCBs is too slow or nonexistent.
I	General Electric—Woods Pond** Pittsfield, MA RCRA Lead (Federal)	Joan Blake (202)260-6236 Federal (or national) organization	Sediments (PCBs) Volume: 250 gallons	Full-scale bioremediation is not planned. Laboratory-scale and pilot-scale studies are being conducted.	Sediments: PCBs, 2 ppm (performance-based).	In situ treatment, confined treatment facility for sediments. Nutrient addition. Anaerobic conditions, indigenous organisms. Nonbiological technologies: incineration, flotation separation.	At present there is no known way to speed up bioremediation of PCBs to a rate that would make technology commercially viable as an option for site cleanup.
I	Iron Horse Park, Operable Unit 1 (B&M Lagoon)** Billerica, MA CERCLA Enforcement Lead	Don McElroy (617)223-5571 Federal (or national) organization	Sludge / vadose soil (PAHs, TPHs) Volume: 20,000 cubic yards % of total vol. at site: 100%	Full-scale remediation has been underway since 05/92. Laboratory-scale studies were completed 01/88. Pilot-scale studies were completed 09/93. Total expected cost: $2M.	Sludge: PAHs, 1 ppm; TPHs, 5,000 ppm (risk-based). Vadose soil: PAHs, 1 mg/kg; TPHs, 5,000 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms.	Cold weather creates a short season. There is a fair amount of "weathered" hydrocarbons which reduces the percentage of total hydrocarbons which can be remediated quickly.
I	Sylvester** Nashua, NH CERCLA State Lead Process 1	Chet Janowski (617)573-9623 Federal (or national) organization Paul Hiertzler (603)882-3631 State (or provincial) organization	Ground water (benzene, chloroform, MEK, 1,1,2-TCA, chlorobenzene, 1,1-DCA, 1,1,1-TCA, methylene chloride, methylmethacrylate, PCE, phenols, TCE, toluene, trans-1,2-DCA, vinyl chloride)	Predesign.	Ground water: vinyl chloride, 95 ppb; benzene, 340 ppb; chloroform, 1,505 ppb; MEK, 8,000 ppb; PCE, 57 ppb; phenols, 400 ppb; TCE, 1,500 ppb; 1,1,2-TCA, 1.7 ppb; chlorobenzene, 110 ppb; methylene chloride, 12.3K ppb; toluene, 2,900 ppb; 1,1-DCA, 1.5 ppb; trans-1,2-DCA, 1,800 ppb; 1,1,1-TCA, 200 ppb; methylmethacrylate, 350 ppb (New Hampshire Drinking Water Standards).	Ex situ treatment, extended aeration.	There have been problems providing enough nutrients to maintain an active biomass.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
	Process 2		Ground water (benzene, chloroform, MEK, 1,1,2-TCA, chlorobenzene, 1,1-DCA, 1,1,1-TCA, methylene chloride, methylmethacrylate, PCE, phenols, TCE, toluene, trans-1,2-DCA, vinyl chloride) Volume: 75 gallons per minute	Full-scale remediation has been underway since 01/86. Pilot-scale studies were completed 01/83.	Ground water: vinyl chloride, 95 ppb; benzene, 340 ppb; chloroform, 1,505 ppb; MEK, 8,000 ppb; PCE, 57 ppb; phenols, 400 ppb; TCE, 1,500 ppb; 1,1,2-TCA, 1.7 ppb; chlorobenzene, 110 ppb; methylene chloride, 12.3K ppb; toluene, 2,900 ppb; 1,1-DCA, 1.5 ppb; trans-1,2-DCA, 1,800 ppb; 1,1,1-TCA, 200 ppb; methylmethacrylate, 350 ppb (New Hampshire Drinking Water Standards).	Ex situ treatment, activated sludge.	There have been problems providing enough nutrients to maintain an active biomass. An evaluation process is underway, which will conclude at the end of 1994. After this evaluation a decision will be made concerning the next step.
II	American Linen** Stillwater, NY CERCLA State Lead	Frank Peduto (518)457-9412 State (or provincial) organization Liz Rovers (518)786-7400 Contractor/ engineering firm	Soil (BTEX lube oil, PAHs, VOCs) Volume: 4,375 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 08/92. Started 07/91.	Soil: TCLP to meet soil guidance levels.	Ex situ land treatment. Aerobic conditions, indigenous organisms.	None.
II	FAA Technical Center—Area D** Atlantic County, NJ CERCLA Enforcement Lead	Carla Struble (212)264-4595 Federal (or national) organization Ian Curtis (609)633-1455 State (or provincial) organization Keith Buch (609)484-6644 Federal (or national) organization	Saturated soil (BTEX jet fuel) / ground water (NAPLs)	Full-scale remediation is planned. Currently being installed. Pilot-scale studies have been completed.	Saturated soil: New Jersey Soil Action Levels. Ground water: New Jersey MCLs.	In situ treatment, in situ ground water bioremediation, in situ soil bioremediation (in situ land treatment). Nutrient addition.	The ROD was signed in 1989, and the design has been approved since 1992. However, there have been delays in the implementation of full-scale bioremediation.
II	General Electric—Hudson River** NY CERCLA Enforcement Lead	Jim Harrington (518)485-8792 State (or provincial) organization Ajay Schroff (518)457-3957 State (or provincial) organization	Sediments (PCBs) Volume: 150 cubic feet	Full-scale remediation is planned. Laboratory-scale studies have been completed. Pilot-scale studies were completed 01/92. Incurred cost: $2.6M.	Not yet established.	In situ treatment, confined treatment facility for sediments. Aerobic conditions, indigenous organisms.	This process is at the RI/FS stage. The above experiment was completed, and bioremediation is still being considered. Onsite experiments in bioremediation of PCBs are continuing to occur. There are questions surrounding the viability of PCB bioremediation, and nobody has shown yet that it is viable.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
II	General Motors—Central Foundry Division** Massena, NY CERCLA Enforcement Lead	Lisa Carson (212)264-6857 Federal (or national) organization	Sediments / sludge / soil (PCBs) Volume: 350,000 cubic yards	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 12/93. Started 04/93.	Sediments: PCBs, 1 ppm (risk-based). Sludge: PCBs, 10 ppm (risk-based). Soil: PCBs, 10 mg/kg (risk-based).	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: chemical extraction, chemical treatment, thermal desorption.	Oil and grease in samples hindered efficiency of bioremediation. Three techniques were tested; bioremediation, solvent extraction, and thermal desorption. Final results are not yet complete, but it appears that the recommendation will be that thermal desorption be employed. Bioremediation was not able to get the contaminant concentrations down to acceptable levels, no further than around 100 ppm.
II	Knispel Construction Site** Horseheads, NJ UST Lead (State)	Frank Peduto (518)457-9412 State (or provincial) organization	Soil / ground water (petroleum)	Full-scale remediation was completed 10/89. Started 01/89. Laboratory-scale studies have been completed. Incurred cost: $250K.	Soil: petroleum, 5 µg/kg (drinking water standards). Ground water: petroleum, 5 ppb (drinking water standards).	In situ treatment, in situ ground water bioremediation, in situ soil bioremediation (in situ land treatment). Hydrogen peroxide, nutrient addition (RESTORE 375). Aerobic conditions, indigenous organisms.	None.
II	Mobil Terminal** Buffalo, NY CERCLA Enforcement Lead	Robert Leary (716)851-7220 Federal (or national) organization Sal Calandra (716)851-7220 State (or provincial) organization	Soil (diesel, gasoline) Volume: 15,000 cubic yards % of total vol. at site: 100%	Full-scale remediation has been underway since 07/91. Laboratory-scale and pilot-scale studies have been completed.	Soil: NYDEC guidance values based on TCLP.	Ex situ land treatment. Aerobic conditions, exogenous and indigenous organisms. Nonbiological technologies: vacuum extraction.	In this ongoing process, treated soil remains on site at Mobil Terminal. An air extraction system was installed in summer 1991 to enhance bioremediation in part of the biocell.
II	Nascolite** Millville, NJ CERCLA Enforcement Lead	Farnaz Saghafi (212)264-4665 Federal (or national) organization Anton Navarajah (609)633-6798 State (or provincial) organization Kim O'Connell (212)264-8127 Federal (or national) organization	Ground water (methylmethacrylate organics)	Full-scale remediation is planned. Currently in design. Laboratory-scale studies were completed 06/92. Started 04/92. Pilot-scale studies were completed 06/94. Started 02/93.	Ground water: methylmethacrylate organics, 560 ppb (risk-based).	Ex situ treatment, fluidized bed, plug flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: filtration.	Design stage will be finished in April 1995. After this, a contractor will be hired for the construction stage.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
II	Niagara Mohawk Power Corporation Saratoga Springs, NY CERCLA Enforcement Lead	Edward Newhauser (315)428-3355 Federal (or national) organization Michael Sherman (315)428-6624 Industry	Soil (PAHs)	Laboratory-scale studies were completed 05/92. Started 02/92.	Soil: potential for leaching to ground water.	Ex situ treatment, slurry reactor. Aerobic conditions, indigenous organisms.	Laboratory-scale feasibility study report currently is being prepared. Depending on results, pilot- and full-scale activity may be undertaken. In situ treatment with nutrient addition would be used for soils, and a fluidized bed bioreactor would be used for ground water.
II	Osmose** Buffalo, NY CERCLA State Lead	Jim Harrington (518)485-8792 State (or provincial) organization Jaspal Walia (716)851-7220 State (or provincial) organization	Vadose and saturated soil (BAP, PAHs) / soil (BTEX fuel oil, creosote) Volume: 670 cubic yards % of total vol. at site: 30%	Full-scale remediation has been underway since 09/90. Total expected cost: $125K.	Vadose/saturated soil: BAP, 10 mg/kg; carcinogenic PAHs, 50 mg/kg (risk-based). Soil: creosote, 473 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms.	LNAPLs were found in some areas of the biocell, and PAHs in these areas have not been affected by the bioremediation. LNAPLs recovery and bioremediation are still being performed. Bioremediation is not going in preferred direction. Nonbiological treatment technologies, such as ozone injections, are also being considered as an alternative.
II	Plattsburgh Air Force Base** Plattsburgh, NY Federal Facility	Brady Baker (518)565-5301 Federal (or national) organization Jim Lister (518)457-3976 State (or provincial) organization	Ground water (BTEX free product)	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies were completed 02/94. Started 01/93.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Air permits are being considered by New York State.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
II	Syracuse** Syracuse, NY UST Lead (State)	Harry Warner (315)426-7519 State (or provincial) organization Arnold Barnhardt (716)876-5290 Contractor/ engineering firm	Soil (petroleum) Volume: 5,000 cubic yards	Full-scale remediation was completed 10/91. Started 07/90.	Soil: NY Soil Cleanup Levels.	Ex situ land treatment. Aerobic conditions, indigenous organisms.	The first phase had a late start; cold weather slowed the use of bioremediation. The site was prepared for closure in fall of 1991, but small untreated areas were discovered. This material was separated and moved to an adjacent area for treatment in spring of 1992. The remedial activities at this site have been completed and all soil cleanup levels met.
III	Allied Chrome Works** Baltimore, MD State of Maryland Process 1	Louis DeFilippi (708)391-3251 Industry F. Stephen Lupton (708)391-3224 Industry	Sediments / soil / ground water (hexavalent chromium)	Full-scale bioremediation is not planned. Pilot-scale studies were completed 01/92. Incurred cost: $200K.	Sediments: hexavalent chromium, 0.05 ppm (drinking water standards). Soil: hexavalent chromium, 0.05 mg/kg (drinking water standards). Ground water: hexavalent chromium, 0.05 ppm.	In situ treatment, in situ ground water bioremediation. Nutrient addition (mineral salts and molasses).	Pilot-scale studies in the field indicated that the site geology was too problematic for full-scale investigation and treatment. There were problems with preferential flows. A cap treatment was chosen for full-scale remediation.
	Process 2		Sediments / soil / ground water (hexavalent chromium)	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 01/91. Started 01/90. Incurred cost: $200K.	Sediments: hexavalent chromium, 0.05 ppm (drinking water standards). Soil: hexavalent chromium, 0.05 mg/kg (drinking water standards). Ground water: hexavalent chromium, 0.05 ppm (drinking water standards).	Ex situ treatment, septic tank reactor, completely mixed flow. Anaerobic conditions, indigenous organisms.	Personnel, cost, and time factored into the decision not to continue ex situ treatment in pilot-scale study, even though the lab-scale treatment had given good results.
III	ARC Gainesville, VA RCRA Lead (Federal)	Robert Stroud (215)597-6688 Federal (or national) organization Patrick Grover (804)225-2863 State (or provincial) organization	Soil (chlorobenzene) Volume: 2,000 cubic yards % of total vol. at site: 5%	Full-scale remediation was completed 06/91. Started 10/89.	Soil: chlorobenzene, 0.014 mg/kg (technology effectiveness).	In situ treatment, bioventing. Aerobic conditions, exogenous organisms.	Facility was required to submit a closure plan to the state of VA; however, this requirement no longer exists.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
III	Atlantic Wood** Portsmouth, VA CERCLA Enforcement Lead	Dave Iacono (215)597-8485 Federal (or national) organization Khoa Nguyen State (or provincial) organization	Sediments / soil (PAHs, PCP)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale and pilot-scale studies are planned.	Sediments: PCP, 0.4 mg/kg; PAHs, 25 mg/kg (ecological).	Ex situ land treatment. Aerobic conditions. Nonbiological technologies: in situ soil flushing, soil washing, thermal desorption, incineration.	Feasibility study results currently are being reviewed. Type of treatment will not be determined until review is completed. The presence of dioxins and furans and metals might be a problem.
III	Avtex Fibers** Front Royal, VA CERCLA Enforcement Lead	Bonnie Gross (215)597-0491 Federal (or national) organization	Ground water (carbon disulfide) Volume: 1,000,000 gallons per day	Full-scale remediation is being conducted.	Not yet established.	Ex situ treatment, activated sludge, completely mixed flow. Aerobic conditions, indigenous organisms.	Typical operational and maintenance problems of a wastewater treatment plant.
III	Dover Air Force Base** Dover, DE Federal Facility Process 1	Milton Beck (302)677-6820 Federal (or national) organization Rob Allen (302)323-4540 State (or provincial) organization	Vadose soil (BTEX, TPHs) / ground water (BTEX) Volume: 15,000 cubic yards	Full-scale remediation is planned. Pilot-scale studies have been underway since 11/92. Total expected cost: $180K.	Vadose soil: BTEX, 10 mg/kg; TPHs, 1,000 mg/kg (risk-based). Ground water: risk-based.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction, air sparging.	Site has experienced problems with free product and ground water contamination.
	Process 2		Soil / ground water (solvents) Volume of soil: 50,000 cubic yards Volume of ground water: 175,000 gallons	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies have been underway since 01/93.	Not yet established.	In situ treatment, air sparging. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction.	Site has solvents in ground water, and high iron and manganese.
	Process 3		Vadose soil (BTEX, PAHs, TCE, TPHs)	Pilot-scale studies are planned.	Vadose soil: BTEX, 10 mg/kg; TPHs, 1,000 mg/kg (risk-based).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	None.
	Process 4		Vadose soil (BTEX, TPHs) Volume: 300,000 cubic yards	Full-scale bioremediation is not planned. Pilot-scale studies are planned. Incurred cost: O&M, $100K. Total expected cost: capital, $1.2M.	Vadose soil: TPHs, 1,000 mg/kg; BTEX, 10 mg/kg (risk-based).	In situ treatment, bioventing. Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction, asphalt binding (probably not going to be used).	Site has free product soil contamination under aircraft parking apron. Because of contracting problems, this never got off the ground. Further tests may be conducted.
III	Drake Chemical Lock Haven, PA CERCLA Fund Lead	Roy Schrock (215)597-0913 Federal (or national) organization	Soil / ground water (DCE, fenac, pesticides)	Full-scale remediation is planned. Currently in predesign.	Not yet established.	Attached growth. Aerobic conditions.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
III	L.A. Clarke & Son** Fredericksburg, VA CERCLA Enforcement Lead	Andrew Palestini (215)597-1286 Federal (or national) organization	Sediments / soil (creosote) Volume: 119,000 cubic yards	Full-scale remediation is planned. Currently in design. Pilot-scale studies have been underway since 07/92. Total expected cost: $23M.	Not yet established.	In situ treatment, creosote recovery, landfarming. Anaerobic conditions. Nonbiological technologies: in situ soil flushing.	Consent decree includes a provision allowing responsible party to petition EPA to revise cleanup levels. The petition is not yet completed. Therefore, cleanup goals are not yet defined, and it is not known whether bioremediation would be capable of meeting those goals. Although landfarming is still an option, other cleanup technologies are being considered.
III	Ordnance Works Disposal Area** Morgantown, WV CERCLA Enforcement Lead	Melissa Whittington (215)597-1286 Federal (or national) organization Janet Wolfe (304)558-2745 State (or provincial) organization	Soil (PAHs) Volume: 1 cubic yard	Full-scale remediation is planned. Laboratory-scale studies have been underway since 02/93. Expected completion 12/94. Pilot-scale studies are planned. Total expected cost: $8.3M.	Soil: carcinogenic PAHs, 44.7 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: solidification of inorganics.	A unilateral administrative order was issued June 1990. There may be problems at this site associated with: (1) achieving the cleanup levels, (2) extrapolating data from the treatability studies, and (3) determining usable amendments for the treatability studies. In addition, we are having difficulty with the heterogeneity of the soil. The process is still in the laboratory-scale phase. The pilot-scale phase has not yet been started, and there is no estimate when it will start. There have been many delays. There is no immediate threat to the study. As long as the study is being funded and there are no unsuccessful results, it can be continued.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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III	Texas Eastern Gas Pipeline** Armaugh, PA TSCA Lead (Federal)	Joan Blake (202)260-6236 Federal (or national) organization	Soil (PCBs) Volume: 3 cubic yards	Full-scale remediation is planned. Laboratory-scale and pilot-scale studies are being conducted.	Soil: performance-based.	In situ treatment, in situ soil bioremediation (in situ land treatment). Ex situ treatment, sequencing batch reactor. Nutrient addition, batch flow. Aerobic conditions, exogenous organisms. Nonbiological technologies: solid-phase extraction process (physical separation).	Pilot-scale studies are being carried out by a contractor hired by Texas Eastern.
III	Whitmoyer Labs** Myerstown, PA CERCLA Enforcement Lead	Christopher Corbett (215)597-8186 Federal (or national) organization Noreen Chamberlain (717)657-6319 State (or provincial) organization	Vadose soil / saturated soil (benzene, aniline, PCE, TCE) Volume: 4,000 cubic yards	Full-scale remediation is planned. Currently in predesign. Laboratory-scale and pilot-scale studies are planned.	Vadose soil: benzene, 0.009 mg/kg; TCE, 0.017 mg/kg; PCE, 0.051 mg/kg; aniline, 0.009 mg/kg. Saturated soil: benzene, 0.002 mg/kg; TCE, 0.004 mg/kg; PCE, 0.012 mg/kg; aniline, 0.002 mg/kg.	Ex situ treatment, biological treatment. Nonbiological technologies: chemical treatment, fixation, incineration, containment, pump and treat.	Bioremediation will only be used on a very small portion of the site, since the main contaminant is arsenic. There is one area that is high in organics, but bioremediation is still a couple of years away.
IV	Alabama State Docks** Mobile, AL RCRA-Federal for soil; RCRA-State for ground water Process 1	Jason Darby (404)347-3433 Federal (or national) organization Jennifer Anderson (205)270-5600 State (or provincial) organization	Ground water (PAHs, benzene, PCP)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been completed. Pilot-scale studies are being conducted.	Ground water: benzene, 0.005 mg/L (MCL).	Ex situ treatment, fluidized bed, completely mixed flow. Aerobic conditions, exogenous organisms. Nonbiological technologies: granular activated carbon.	Problems have arisen over regulatory concerns when managing treated material.
	Process 2		Soil (PAHs, PCP)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been completed. Pilot-scale studies are planned.	Soil: risk-based.	Ex situ land treatment.	RCRA land disposal restrictions (LDRs) may interfere with land treatment of contaminated soils. Promulgation of the CAMU rule has provided some relief from LDRs.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
IV	American Creosote Works—Jackson** Jackson, TN CERCLA Fund Lead Process 1	Tony DeAngelo (404)347-7791 Federal (or national) organization Ron Sells (901)423-6600 State (or provincial) organization	Ground water (creosote, PCP)	Full-scale remediation is planned. Laboratory-scale and pilot-scale studies are planned.	Not yet established.	Ex situ land treatment, pile. Aerobic conditions, indigenous organisms.	Hydrogeologic investigation is completed. Remedial action is contingent upon receiving a 10% cost share from state. Funds are available for treatability studies only. This unit, Operable Unit #2, is in the pre-ROD stage. Bioremediation has not yet been selected as a remedy, only a potential one.
	Process 2		Sludge (creosote) / vadose and saturated soil (creosote, PAHs, phenols)	Full-scale remediation is planned. Laboratory-scale and pilot-scale studies are planned.	Not yet established.	Ex situ treatment, aerated lagoon. Aerobic conditions, indigenous organisms.	State may not have 10% cost share for any remedial action to be undertaken. In this Operable Unit #3, bioremediation has not yet been a selected remedy, only a potential one.
IV	American Creosote Works—Pensacola** Pensacola, FL CERCLA Fund Lead Process 1	Mark Fite (404)347-2643 Federal (or national) organization Doug Fitton (904)488-0190 State (or provincial) organization	Soil (PAHs, PCP)	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 11/91. Total expected cost: $5M.	Soil: risk-based.	Ex situ treatment, sequencing batch reactor, slurry reactor, batch flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: soil washing.	Bioremediation was not effective for remediation of dioxins in soils, and it was only effective in degrading PCPs and carcinogenic PAHs at a rate of 30%. Laboratory tests indicated inability to achieve cleanup goals; biotreatment not compatible with dioxin and PCP and PAH contamination discovered at site. Since bioremediation was not successful in meeting the cleanup goals for PCPs and carcinogenic PAHs, the site is no longer pursuing a biotreatment plan. An amended ROD has been proposed and will most likely incorporate a thermal technology.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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	Process 2		Ground water (benzene, acenaphthene, fluoranthene, dibenzofuran, naphthalene, PAHs, PCP) Volume: 152,000,000 gallons	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies are planned. Expected start 01/95. Pilot-scale studies are planned. Expected start 01/96. Total expected costs: capital, $3.9M; total, $5.9M. Costs per year: O&M, $492K.	Ground water: carcinogenic PAHs, 1,100 ppb; benzene, 91 ppb; PCP, 296K ppb; acenaphthene, 9,000 ppb; fluoranthene, 1,500 ppb; naphthalene, 21.9K ppb; dibenzofuran, 44 ppb (alternate conc. limit (ACL)).	In situ treatment, in situ ground water bioremediation. Hydrogen peroxide, nutrient addition (nutrients not yet determined). Aerobic conditions, indigenous organisms. Nonbiological technologies: soil washing, enhanced DNAPL recovery and separation prior to in situ biotreatment of ground water.	Addition of other enhancing agents during DNAPL recovery may inhibit bioremediation. Injection of any nutrients or hydrogen peroxide may be prohibited by State.
	Process 3		Soil (PAHs, PCP)	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 11/91. Total expected cost: $5M.	Soil: risk-based.	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: soil washing.	Bioremediation was not effective for remediation of dioxins in soils. Biotreatment was unable to achieve remedial goals for PCPs and carcinogenic PAHs.
IV	Brown Wood Preserving** Live Oak, FL CERCLA Enforcement Lead	Martha Berry (404)347-2643 Federal (or national) organization Doug Fitton (904)488-0190 State (or provincial) organization	Soil (PAHs) Volume: 9,000 cubic yards	Full-scale remediation was completed 12/91. Started 10/88.	Soil: PAHs, 100 mg/kg.	Ex situ land treatment. Aerobic conditions, indigenous organisms.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
IV	Cabot Koppers** Gainesville, FL CERCLA Enforcement Lead	Martha Berry (404)347-2643 Federal (or national) organization Doug Fitton (904)488-0190 State (or provincial) organization	Soil (PAHs, fluorene, naphthalene, PCP, phenol) Volume: 6,700 cubic yards	Full-scale remediation is planned. Laboratory-scale studies were completed 04/93. Pilot-scale studies are planned.	Soil: carcinogenic PAHs, 0.59 mg/kg; phenol, 4.28 mg/kg; naphthalene, 211 mg/kg; fluorene, 323 mg/kg; PCP, 2.92 mg/kg.	In situ treatment, in situ soil bioremediation (in situ land treatment). Hydrogen peroxide, plate counts, respirometry, analytical assays. Aerobic conditions, indigenous organisms. Nonbiological technologies: soil washing, solidification.	This site is an active facility. The purpose of considering the cleanup was to prevent contamination of the ground water, and it was thought initially that the contamination was only to 6 to 7 feet. Bioremediation was being considered for two source areas under structures, where it was hard to excavate. However, it was suddenly discovered that there was contamination to 25 feet, and that there was a serious DNAPL problem. In addition, the bench-scale bio tests did not show cleanup level achievement. At the present, there is a rethinking of strategy, and work is beginning on the submission of an FS work plan. A pump and treat system for ground water is being set up in order to deal with the DNAPL now, and soil will be dealt with later. A pilot-scale study for the bio is probably the next step.
IV	Cape Fear Wood Preserving** Fayetteville, NC CERCLA Fund Lead	Jon Bornholm (404)347-7791 Federal (or national) organization	Sediments / soil / ground water (PAHs) Volume: 2,600 cubic yards	Full-scale remediation is planned. Currently in design. Laboratory-scale studies were completed 01/90. Pilot-scale studies are planned. Expected start 06/95.	Sediments: PAHs, 3 mg/kg. Soil: PAHs, 100 mg/kg; carcinogenic PAHs, 2.5 mg/kg. Ground water: PAHs, 14 mg/L; carcinogenic PAHs, 10 µg/L.	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: soil washing, solidification.	Laboratory-scale study was terminated due to time constraints. Biodegradation reduced average total PAH levels and carcinogenic PAH levels from 306 mg/kg and 44 mg/kg, respectively, to 50 mg/L and 14 mg/L in 18 days. Pilot-scale work is needed to confirm effectiveness; overall results suggest longer incubation period could result in further reduction of PAHs to below cleanup goals.

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IV	Celanese Fibers Operations** Shelby, NC CERCLA Enforcement Lead	Dewey Williamson (704)482-2411 Industry Bruce Nicholson (919)733-2801 State (or provincial) organization Ken Mallary (404)347-7791 Federal (or national) organization	Ground water (acetone, 1,2-DCE, ethylene glycol) Volume: 93,500 gallons per day	Full-scale remediation is being conducted. Incurred cost: $1.5M.	Ground water: ethylene glycol, 7 ppm; 1,2-DCE, 0.07 ppm (state MCLs).	Ex situ treatment, sequencing batch reactor, batch flow. Aerobic conditions, exogenous and indigenous organisms. Nonbiological technologies: chemical treatment, the front-end technologies used to help out the bioremediation are pH adjustment, equalization tank, and a tank separator to take care of iron. Other technologies used after the bioremediation are air stripping and carbon adsorption.	System has experienced biomass upsets. The cause has not been determined, but measures have been taken to deal with them and have been fairly successful. The ROD did not specify the cleanup levels for chemical specific contaminants. Although the efficiency of the system is monitored based on BOD, COD, and TOC, specific reductions in chemicals of concern have not been analyzed or determined. In the last 5 years, the two-tier extraction well system has averaged 90% removal of TOC and 80% removal of BOC. A total of 460,900 lbs of TOC, 165,000 lbs of COD, and 286,000 lbs of BOD have been removed from the inner-tier well system.
IV	Charleston Air Force Base** Charleston, SC RCRA Lead (Federal)	Al Urrutia (803)566-4978 Federal (or national) organization A.A. "Gussie" Ownby (803)734-4587 State (or provincial) organization Caron Falconer (404)347-3016 Federal (or national) organization	Vadose soil (1,1,1-TCA, BTEX jet fuel, PCE, 1,1-DCE, dichloromethane, TCE, trans-1,2-DCE, vinyl chloride) Volume: 25 cubic yards	Full-scale remediation is planned. Pilot-scale studies were completed 05/94. Started 11/92.	Not yet established.	In situ treatment, bioventing. Oxygen source. Aerobic conditions, indigenous organisms.	Bioventing will be difficult due to high ground water table and seasonal variation of ground water elevation and direction. Studies are being conducted to assess if bioventing should be implemented at this site and also to determine what technologies would be most effective.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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IV	Coleman-Evans** White House, FL CERCLA Fund Lead	Tony Best (404)347-2643 Federal (or national) organization Kelsey Helton (904)488-0190 State (or provincial) organization	Soil (dioxin, PCP) Volume: 27,000 cubic yards	Full-scale bioremediation is not planned. Laboratory-scale studies have been completed. Total expected cost: $8.6M.	Soil: PCP, 25 mg/kg.	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, exogenous organisms. Nonbiological technologies: soil washing, solidification/stabilization.	Problem existed with wood chip removal from soils. Dioxins have been identified and were found to obstruct the biodegradation process. The identification of dioxin in the soil increased the contaminated area from 27,000 cubic yards to 52,000 cubic yards. No document of the treatability studies was ever drafted. Bioremediation was ineffective for the removal of dioxins although the process was effective in degrading PCP in treatability studies. Bioremediation is no longer being considered at the site, and the ROD is being amended. Thermal desorption, capping, or incineration (all in conjunction with ground water pump and treat) are alternatives being considered to address dioxin contamination.
IV	Dubose Oil** Cantonment, FL CERCLA Enforcement Lead	Mark Fite (404)347-2643 Federal (or national) organization George Linder (904)488-0190 State (or provincial) organization Greg Wieland (404)325-0770 Contractor/ engineering firm	Soil (PCP, benzene, DCE, PNAs, TCE, xylene) Volume: 20,000 tons % of total vol. at site: 46%	Full-scale remediation has been underway since 11/93. Laboratory-scale studies were completed 11/88. Started 01/88. Pilot-scale studies are planned. Total expected cost: $3M.	Soil: PNAs, 50 mg/kg; PCP, 50 mg/kg; xylene, 1.5 mg/kg; benzene, 10 mg/kg; TCE, 0.05 mg/kg; DCE, 0.07 mg/kg (risk-based).	Ex situ treatment, pile. Aerobic conditions, indigenous organisms. Nonbiological technologies: carbon adsorption for treatment of wastewater.	Pilot study was delayed due to difficulty in locating soils exceeding cleanup levels. However, full-scale operation proceeded on schedule.

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IV	Escambia Wood Preserving Site—Brookhaven** Brookhaven, MS CERCLA Fund Lead	De'Lyntoneus Moore (404)347-3931 Federal (or national) organization Kim Kreiton (513)569-7328 Federal (or national) organization	Soil (creosote, PCP) Volume: 200 cubic yards	Full-scale bioremediation is not planned. Pilot-scale studies were completed 11/92. Started 06/92.	Soil: risk-based.	Ex situ treatment, white rot fungi treatment. Aerobic conditions, exogenous and indigenous organisms.	There is a lack of information on the success of this technology at field scale; however, the field treatability study showed reduction in PCP and creosote—up to 86% for PCP, and 96% for 3-ringed PAH creosote compounds.
IV	Koppers/Florence** Florence, SC RCRA Lead (Federal) Process 1	Mike Arnett (404)347-7603 Federal (or national) organization	Soil (PAHs, PCP)	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies are planned. Expected completion 07/95.	Soil: risk-based.	Ex situ land treatment. Aerobic conditions, exogenous and indigenous organisms. Nonbiological technologies: ground water extraction, pretreatment, and discharge to a POTW.	There have been many negotiations involved with various parties, including the state, trying to address all the concerns. The main state concern is of the contaminants being forced further into the aquifer. It took a while to get the document to the approval stage. The general lack of experience of others doing in situ treatment with these types of waste was also an obstacle.
	Process 2		Vadose soil (PAHs, PCP)	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies are planned. Expected completion 07/95.	Vadose soil: risk-based.	In situ treatment, in situ soil bioremediation (in situ land treatment). Hydrogen peroxide. Aerobic conditions, exogenous and indigenous organisms. Nonbiological technologies: ground water extraction, pretreatment, and discharge to a POTW.	There have been many negotiations with the various parties involved, including the state, trying to address all concerns. The main concern of the state is of the contaminants being forced further into the aquifer. It took a while to get the document to the approval stage. The general lack of experience of others doing in situ treatment with these types of wastes is also an obstacle.
IV	Langdale Facility Sweetwater, TN RCRA Lead (Federal)	Charles Burroughs (615)741-3424 Federal (or national) organization	Sludge / soil (creosote)	Full-scale remediation was completed 01/89.	Not supplied.	Ex situ land treatment, nutrient addition, and cometabolite. Exogenous organisms.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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IV	Orkin Facility** Fort Pierce, FL RCRA Lead (State)	Bob Hines (404)888-2195 State (or provincial) organization Ron Lewis (513)569-7856 Federal (or national) organization Ron Hicks (510)671-2387 Contractor/ engineering firm	Soil (chlordane, heptachlor) Volume: 750 cubic yards	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been underway since 03/93. Expected completion 10/94. Pilot-scale studies are planned.	Soil: risk-based.	In situ treatment, in situ soil bioremediation (in situ land treatment). Oxygen source, nutrient addition. Aerobic conditions, exogenous organisms. Nonbiological technologies: chemical treatment.	None.
IV	Shavers Farm Lafayette, GA CERCLA Fund Lead	Chuck Eger (404)347-3931 Federal (or national) organization	Soil (benzoic acid, benzonitrile, dicamba, dichlorosalicyclic acid)	Pilot-scale studies have been completed.	Soil: dicamba, 25 mg/kg; benzoic acid, 25 mg/kg; dichlorosalicyclic acid, 25 mg/kg; benzonitrile, 25 mg/kg.	Bioremediation treatment not yet established.	Pilot bench-scale treatability studies are being reviewed.
IV	Silvex** Saint Augustine, FL State Lead	George Heuler (904)488-0190 State (or provincial) organization	Ground water (acetone, benzene, 2-butanone, chloroform, 1,1,1-TCA, 2,4-dimethylphenol, cresols, ethylbenzene, methylene chloride, MIBK, toluene)	Full-scale remediation has been underway since 10/93. Laboratory-scale studies were completed 08/91. Started 01/91. Pilot-scale studies were completed 10/92. Started 01/92. Incurred costs: capital, $560K; O&M, $330K. Total expected costs: capital, $585K; O&M, $400K; total, $910K.	Ground water: acetone, 700 µg/L; benzene, 1 µg/L; chloroform, 0.7 µg/L; cresols, 700 µg/L; ethylbenzene, 39 µg/L; 2-butanone, 680 µg/L; methylene chloride, 7 µg/L; toluene, 2,000 µg/L; 1,1,1-TCA, 200 µg/L; MIBK, 350 µg/L; 2,4-dimethylphenol, 39 µg/L.	Ex situ treatment, fixed film, completely mixed flow. Aerobic conditions, exogenous organisms. Nonbiological technologies: soil solidification.	The entire 16 gpm system was designed, mobilized, and constructed as part of an IRM project in 9 weeks. The greatest obstacle has been the treatment of vapors/off-gas from the bioreactor and equalization tank, which will react with a vapor GAC system, due to heat liberated from the oxidation of ketones with charcoal. Not yet mobilized is a large-scale biofilter system, by E, G, & G which will be constructed by mid-summer, and is "guaranteed to remove the very pungent odors," which include mercaptons, from the ground water.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
IV	Southeastern Wood Preserving** Canton, MS CERCLA Fund Lead	Don Rigger (404)347-3931 Federal (or national) organization Sharyn Erickson, Contracting Officer (404)347-2374 Federal (or national) organization Doug Jerger (800)326-4932 Contractor/ engineering firm	Soil (total PAHs) Volume: 8,000 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 06/94. Total expected cost: $2.2M.	Soil: total PAHs, 950 mg/kg (risk-based).	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, exogenous and indigenous organisms. Nonbiological technologies: soil washing.	Variability of analytical results using different soil extraction methods was highly significant. Even within each method, there was wide variability in treatment results, possibly from analytical methods or from the less-than-expected homogeneity in the soil slurries.
IV	Stallworth Timber** Beatrice, AL RCRA Lead (State) and RCRA Lead (Federal)	Jason Darby (404)347-3433 Federal (or national) organization Jeff Kitchens (205)271-7726 State (or provincial) organization	Soil / ground water (creosote, PCP)	Full-scale remediation is planned. Currently in predesign.	Not yet established.	In situ treatment, in situ soil bioremediation (in situ land treatment). Ex situ treatment, activated sludge, completely mixed flow. Aerobic conditions, exogenous and indigenous organisms. Nonbiological technologies: chemical treatment, clarification, ultraviolet oxidation.	Treatment has not yet begun.
IV	White House Waste** White House, FL CERCLA Fund Lead	Tony Best (404)347-2643 Federal (or national) organization Marvin Collins (904)488-0190 State (or provincial) organization	Soil (BAP, 1,4-dichlorobenzene, benzene, 2-methylnaphthalene, chlorobenzene, di-n-butyl phthalate, methylene chloride, naphthalene, PCB 1260, PCE, phenol, TCE, toluene) / ground water (acetone, BAP, benzene, bis(2-ethylhexyl)phthalate, carbon disulfide, 2-methylnaphthalene, di-n-butyl phthalate, ethylbenzene, m-cresol, MEK, naphthalene, p-cresol, phenol, TCE, toluene, xylene) Volume: 56,000 cubic yards	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies were completed 09/91. Total expected costs: capital, $15.5M; O&M, $3.4M.	Soil: benzene, 1.13 µg/kg; BAP, 0.192 mg/kg; chlorobenzene, 970 mg/kg; 1,4-dichlorobenzene, 0.012 mg/kg; methylene chloride, 29.3 mg/kg; PCB 1260, 0.09 mg/kg; 2-methylnaphthalene, 2.2 mg/kg; naphthalene, 0.261 mg/kg; phenol, 0.549 mg/kg; PCE, 4.3 mg/kg; toluene, 14.4K mg/kg; TCE, 0.0447 mg/kg (risk-based). Ground water: acetone, 0.0016 mg/L; benzene, 0.005 mg/L; BAP, 0.0002 mg/L; bis(2-ethylhexyl)phthalate, 0.004 mg/L; carbon disulfide, 1.64 mg/L; ethylbenzene, 0.7 mg/L; MEK, 8.46 mg/L; m-cresol, 0.85 mg/L; naphthalene, 9,700 mg/L; 2-methylnaphthalene, 0.067 mg/L; phenol, 10 mg/L; toluene, 1 mg/L; TCE, 0.005 mg/L; xylene, 10 mg/L; p-cresol, 0.85 mg/L.	Ex situ treatment, slurry reactor, batch flow. Aerobic conditions, exogenous organisms. Nonbiological technologies: soil washing, solidification/stabilization.	Bioremediation is a proposed remedy, presently under public comment. If accepted, an amended ROD will follow. Solidification/stabilization will follow bioremediation in the treatment train due to the presence of lead.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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V	Allied Chemical** Ironton, OH CERCLA Enforcement Lead Process 1	Tom Alcamo (312)886-7278 Federal (or national) organization Kay Gossett (614)385-8501 State (or provincial) organization	Sediments (PAHs) Volume: 1,000 cubic yards	Full-scale remediation is planned. Currently in design. Laboratory-scale and pilot-scale studies have been completed.	Sediments: carcinogenic PAHs, 1 ppm (risk-based).	Ex situ treatment, reactor used to grow microorganisms where a magnetic field is applied, then circulated to two engineered cells. Aerobic conditions, indigenous organisms.	None.
	Process 2		Sediments (PAHs) Volume: 460,000 cubic yards	Full-scale remediation is planned. Currently in design. Expected start 06/95. Laboratory-scale studies were completed 09/92. Pilot-scale studies have been completed.	Sediments: carcinogenic PAHs, 1 mg/kg (risk-based).	In situ treatment, in situ sediment bioremediation. Oxygen source, nutrient addition. Aerobic conditions, indigenous organisms. Nonbiological technologies: incineration with onsite reuse of waste heat; pump and treat for ground water.	Concentrations of contaminants are highly variable, making confirmation of cleanup difficult.
	Process 3		Sediments (PAHs) Volume: 30,000 cubic yards	Full-scale remediation is planned. Currently in design. Expected start 06/95. Laboratory-scale and pilot-scale studies have been completed.	Sediments: carcinogenic PAHs, 1 ppm (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: incineration with reuse of onsite waste heat; pump and treat for ground water.	None.
V	Aristech Chemical** Haverhill, OH RCRA Lead (Federal) Process 1	Bud Smith (614)533-5412 Industry Scott Schermerhorn (614)385-8501 State (or provincial) organization Dan Biach (614)533-5412 Industry	Vadose and saturated soil (phenol) Volume: 10,000 cubic yards % of total vol. at site: less than 1%	Full-scale remediation has been underway since 07/94. Laboratory-scale studies were completed 06/94. Started 05/94. Pilot-scale studies have been completed.	Vadose/saturated soil: phenol, 10 mg/kg (risk-based).	In situ treatment, bioventing. Oxygen source, nutrient addition. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction, thermal desorption.	None.

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	Process 2		Vadose soil (phenol) Volume: 1,200 cubic yards	Full-scale bioremediation is not planned. Laboratory-scale studies have been completed.	Vadose soil: phenol, 10 mg/kg (risk-based).	In situ treatment, in situ soil bioremediation (in situ land treatment). Nutrient addition (nitrogen-phosphorus slurry). Aerobic conditions, exogenous and indigenous organisms.	Soil moisture and temperature were the most difficult factors to control. The land treatment process also required constant aeration to be effective. Preliminary studies were done to determine what remediation method would be the most effective process in treating the contaminated site. Land treatment had been considered but has since been determined to be less effective than bioventing.
V	Autostyle** Kentwood, MI CERCLA Enforcement Lead	Bonnie White (616)456-5071 State (or provincial) organization	Ground water (alcohol, aromatic ketones)	Full-scale remediation has been underway since 09/90. Laboratory-scale and pilot-scale studies have been completed.	Not yet established.	Ex situ treatment, fixed film, completely mixed flow. Aerobic conditions. Nonbiological technologies: vacuum extraction, soil vapor extraction for product recovery and soil treatment.	None.
V	B&F Trucking Company** Rochester, MN UST Lead (State)	Don Miless (612)297-8577 State (or provincial) organization Stephen Thompson (612)297-8603 State (or provincial) organization	Soil / ground water (BTEX lube oil) Volume: 700 cubic yards % of total vol. at site: 75%	Full-scale remediation was completed 12/92. Started 04/91. Laboratory-scale studies were completed 01/90. Pilot-scale studies have been completed. Incurred cost: $341K.	Soil: BTEX, 50 mg/kg (risk-based). Ground water: 100 x MN Department of Health RALs.	Ex situ treatment, sequencing batch reactor, completely mixed flow. Aerobic conditions, indigenous organisms.	The aboveground bioreactor portion of the process went well; however, there were problems with the reinfiltration step, due to water levels. The upgradient infiltration gallery was periodically swamped by rising ground water level, so the treated water could not be infiltrated. Increase in the iron concentration in ground water caused iron bacteria and resulting "slime" to accumulate on the surface of pipes and other process equipment. Site now has converted to nonbiological process.

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V	Bendix Corporation/Allied Automotive Site** St. Joseph, MI CERCLA Enforcement Lead Process 1	John Kuhns (312)353-6556 Federal (or national) organization Bill Harmon (517)373-4951 State (or provincial) organization	Vadose soil (DCA, TCE)	Full-scale remediation is planned. Currently being installed. Expected start 09/94. Laboratory-scale studies have been completed. Pilot-scale studies are planned.	Not yet established.	Ex situ treatment, fixed film, plug flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction.	None.
	Process 2		Ground water (DCE, DCA, TCE, vinyl chloride)	Full-scale remediation is planned. Laboratory-scale studies are being conducted.	Not yet established.	In situ treatment, in situ ground water bioremediation. Aerobic and anaerobic conditions, indigenous organisms.	Recent sampling found elevated levels of ethene in the aquifer, implying an extensive degree of intrinsic mineralization. This unassisted, intrinsic process of biodegradation may be adequate to remediate the ground water.
V	BP Oil Company** Lima, OH RCRA Lead (Federal)	Gary Vonderembse (419)226-2744 Federal (or national) organization	Soil (BAP, 1-methylchrysene, 1-methylnaphthalene, benzo(a)anthracene, chrysene) Volume: 9 acres	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 11/88.	Soil: BAP, 38 µg/kg; benzo(a)anthracene, 38 µg/kg; chrysene, 37 µg/kg; 1-methylchrysene, 37 µg/kg; 1-methylnaphthalene, 16 µg/kg (residential risk-based scenario).	In situ treatment, in situ soil bioremediation (in situ land treatment). Nutrient addition (anhydrous ammonia). Aerobic conditions, indigenous organisms.	Land treatment permit was denied. Application of oily sludge took place in November 1990. Site is working to achieve risk levels of 10^{-6} or 10^{-5} before closing, which will determine the land's final use. Facility is waiting for approval of the closure plan it submitted in November 1992. Additionally, assessments are being made of moving from a residential risk-based plan to an industrial risk-based plan.

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V	Burlington Northern Brainerd, MN CERCLA—State to start; RCRA—Federal since 1986	David Seep (913)661-7015 Federal (or national) organization Frederick Jenness (612)297-8470 State (or provincial) organization Richard Trnax (303)493-3700 Contractor/ engineering firm	Vadose soil / ground water (PCP) Volume: 10,000 cubic yards % of total vol. at site: 100%	Full-scale remediation is being conducted. Pilot-scale studies were completed 01/86.	Not yet established.	Ex situ land treatment, nutrient addition. Aerobic conditions, indigenous organisms. Nonbiological technologies: thermal desorption and pump and treat for ground water.	None.
V	Cliff/Dow Disposal Site** Marquette, MI CERCLA Enforcement Lead	Ken Glatz (312)886-1434 Federal (or national) organization Bruce Van Ottern (517)373-8427 State (or provincial) organization	Vadose soil (PAHs) Volume: 9,000 cubic yards	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 08/93. Started 12/92.	Vadose soil: PAHs, 0.3 mg/kg (health-based).	Ex situ treatment, pile, forced air biological treatment (FABT). Aerobic conditions, indigenous organisms.	Biotreatment process did not reduce PAHs to below risk-based numbers in a reasonable time frame (22 weeks). Further sampling is being conducted to determine what alternative method, if any, should be implemented to remediate the site. Currently, in situ and excavation techniques are being considered.
V	Fisher-Calo LaPorte, IN CERCLA Fund Lead	Jeff Gore (312)886-6552 Federal (or national) organization	Soil (PCBs) / ground water (DCE, DCA, TCE)	Predesign.	Ground water: TCE, 5 ppb; DCE, 70 ppb; DCA, 200 ppb (drinking water standards).	Bioremediation treatment not yet established.	There is only a remote possibility that bioremediation will be used to remediate entire site.
V	Galesburg/Koppers** Galesburg, IL CERCLA State Lead	Brad Bradley (312)886-4742 State (or provincial) organization Steve Davis (217)785-3913 State (or provincial) organization	Soil (chlorophenol, PCP, PAHs, phenols, PNAs)	Full-scale remediation is planned. Currently in predesign.	Not yet established.	In situ treatment, in situ soil bioremediation (in situ land treatment). Nutrient addition.	None.
V	Hentchells** Traverse City, MI UST Lead (State) Process 1	Ann Emington (616)775-9727 State (or provincial) organization	Ground water (PAHs)	Full-scale remediation is being conducted. Pilot-scale studies were completed 08/93. Started 06/93.	Ground water: risk-based.	In situ treatment, air sparging. Oxygen source. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction.	Isolated "hot spots" are currently being treated with air sparge/soil vapor extraction.

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	Process 2		Soil (BTEX, PAHs) / ground water (BTEX)	Full-scale remediation was completed 03/89. Started 09/85.	Soil: risk-based. Ground water: risk-based.	In situ treatment, in situ ground water bioremediation, in situ soil bioremediation (in situ land treatment). Nutrient addition (soils, (mono- and di-sodium phosphate, ammonium choride), water, (mono- and di-sodium phosphate, ammonium chloride)). Aerobic conditions, indigenous organisms.	Iron-forming bacteria clogged the carbon system. Site is pursuing final cleanup of residue at leading edge of plume and needs soil verification.
V	Joslyn MFG** Brooklyn Center, MN CERCLA State Lead	Ann Bidwell (612)296-7827 State (or provincial) organization John Betcher (612)296-7821 State (or provincial) organization Kevin Turner (312)886-4444 Federal (or national) organization	Vadose soil (PAHs, PCP) Volume: 67,000 cubic yards % of total vol. at site: 35%	Full-scale remediation has been underway since 08/89. Expected completion 08/95. Laboratory-scale studies have been completed.	Vadose soil: PCP, 150 mg/kg; PAHs, 100 mg/kg (dermal contact).	Ex situ land treatment. Nutrient addition (inorganic nitrogen and phosphorous). Aerobic conditions, indigenous organisms. Nonbiological technologies: ground water pump out system with nonbiological treatment.	Due to extreme rainfall in May 1992, part of the land treatment unit was under water. Flooding has delayed treatment of lift 2 soil. Lift 3 (TL3) soils were applied to LTU in fall 1992. Cool wet weather slowed treatment of TL3. If treatment goals are met in 1994, the fourth and final soil lift (TL4) will be applied.
V	K.I. Sawyer Air Force Base** Marquette, MI Federal Facility Process 1 Process 2	Gary Koski (906)372-2342 Federal (or national) organization Mark Petrie (906)228-6561 State (or provincial) organization	Vadose soil (benzene, toluene, xylene) Vadose soil (benzene, toluene, xylene)	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies have been completed. Full-scale remediation is planned. Currently in predesign. Pilot-scale studies are being conducted.	Vadose soil: benzene, 20 µg/kg; toluene, 16K µg/kg; xylene, 6,000 µg/kg (MDNR Act 307 Type B Criteria). Vadose soil: benzene, 20 µg/kg; toluene, 16K µg/kg; xylene, 6,000 µg/kg (MDNR Act 307 Type B Criteria).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Nonbiological technologies: a twelve-week study was conducted from November 1990 to February 1991 to evaluate the effectiveness of dual pump versus single pump hydrocarbon recovery for free product on the water table. In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Site is located in northern U.S., near Lake Superior. Accumulation of snow and freezing temperatures for more than 6 months of the year make field work and system operation difficult. Site is located in northern U.S., near Lake Superior. Accumulation of snow and freezing temperatures for more than 6 months of the year make field work and system operation difficult.

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V	Kenworth Truck Company** Chillicothe, OH CERCLA State Lead	Kay Gossett (614)385-8501 State (or provincial) organization	Vadose soil (TPHs) / ground water (benzene, ethylbenzene, acetone, toluene, xylene)	Full-scale remediation has been underway since 03/94.	Vadose soil: TPHs, 40 mg/kg. Ground water: benzene, 0.005 ppm; toluene, 1 ppm; ethylbenzene, 0.7 ppm; xylene, 10 ppm; acetone, 0.25 ppm.	In situ treatment, in situ ground water bioremediation. Ex situ treatment, GAC bioreactor. Hydrogen peroxide, nutrient addition (nitrogen, phosphorus), completely mixed flow. Aerobic conditions, indigenous organisms.	None.
V	Kincheloe Former Air Force Base** Kinross County, MI Federal Facility	Richard Leonard (716)879-4418 Federal (or national) organization Judith Leithner (716)879-4234 Federal (or national) organization	Vadose soil (BTEX, benzene, ethylbenzene, toluene, xylene)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies are planned. Pilot-scale studies are being conducted. Expected completion 09/94. Total expected cost: $190K.	Vadose soil: xylene, 6,000 µg/kg; benzene, 0.02 mg/kg; ethylbenzene, 14 mg/kg; toluene, 16 mg/kg (Michigan health risk-based standard).	In situ treatment, bioventing. Oxygen source, nutrient addition (nitrogen and phosphorous may be used depending on initial test results), additional moisture may be used depending on initial test results. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction.	Soil at site contains low concentrations of TCE, which will be removed by soil vapor extraction. Lab-scale tests will be performed only if (a) bio-oxidation rate is much lower than expected during pilot trials and (b) regulatory agency requests them. No date for lab-scale tests is scheduled due to provisional nature of tests. A contract has been awarded for the pilot-scale studies to Engineering-Science, Inc. Full-scale remediation will depend on results of pilot trials.
V	MacGillis and Gibbs Company Site** New Brighton, MN CERCLA Fund Lead	Daryl Owens (312)886-7089 Federal (or national) organization Douglas Robohm (612)296-7717 State (or provincial) organization	Ground water (PAHs, PCP)	Full-scale remediation is planned. Currently in design. Expected start 11/95. Pilot-scale studies were completed 09/89. Started 07/89. Total expected cost: capital, $1.6M. Cost per year: O&M, $330K.	Ground water: POTW pretreatment standards.	Ex situ treatment, fixed film, plug flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: soil washing and soil incineration are under consideration.	A pilot-scale bioremediation system was tested on site under the SITE program. The results are in a report dated September 1991 (EPA/540/A5-91/001).
V	Marathon Station-Ervines** Kentwood, MI State Lead	Bonnie White (616)456-5071 State (or provincial) organization	Ground water (BTEX, gasoline)	Full-scale remediation has been underway since 01/88. Laboratory-scale and pilot-scale studies have been completed.	Ground water: health risk.	Ex situ treatment, fixed film, plug flow. Aerobic conditions. Nonbiological technologies: carbon polish unit to ensure compliance with NPDES permit. Company has been considering soil vapor extraction to enhance process but has not taken steps to implement. Originally also had some product separation (gravity).	System was designed as a decay phase reactor, so periodically it has to shut down to allow regrowth of cultures. (This has occurred only once.)

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V	Mayville Fire Department** Mayville, MI UST Lead (State)	Dennis Gervin (517)386-7265 State (or provincial) organization	Ground water (benzene, ethylbenzene, toluene, xylenes) Volume of saturated soil: 1,500 cubic yards % of total vol. at site: 100%	Full-scale remediation has been underway since 05/90. Expected completion 12/94. Incurred costs: capital, $12K; O&M, $4,000.	Ground water: benzene, 1 ppb; toluene, 800 ppb; ethylbenzene, 70 ppb; xylenes, 300 ppb.	In situ treatment, air sparging. Aerobic conditions, indigenous organisms.	Non-detectable levels have been achieved. However, the project has not yet been closed out. Cleanup appears to be complete, but monitoring needs to occur for three more quarters.
V	Michigan Air National Guard** Battle Creek, MI Federal Facility	Fred Vollmerhausen (616)969-3233 Federal (or national) organization	Vadose soil (BTEX)	Full-scale remediation is planned. Currently in design. Remediation expected completion 09/94. Pilot-scale studies were completed 09/93. Started 09/92. Incurred costs: capital, $3,000; O&M, $48. Total expected cost: O&M, $1,268. Cost per year: O&M, $436.	Not supplied.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	None.
V	Moss-American** Milwaukee, WI CERCLA Enforcement Lead	Ross Hart (312)886-4844 Federal (or national) organization	Sediments / soil (creosote) Volume: 80,000 cubic yards	Full-scale remediation is planned. Laboratory-scale studies have been completed. Pilot-scale studies are planned.	Sediments: creosote, 6.1 mg/kg (risk-based). Soil: creosote, 6.1 mg/kg (risk-based).	Ex situ treatment, slurry reactor. Nutrient addition (phosphorus, nitrogen), batch flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: soil washing.	Percent of clay in soil/sediment may reduce the efficiency of the system. Surfactants used in working process may interfere with bioslurry system. Also, laboratory-scale studies produced erratic results. The bioslurry technique was shown to remove 80-90% of two-, three-, and four-ring PAHs but only 50-60% of five-ring PAHs. The differing degrees of degradation have suggested a review of the bioslurry method. Further studies and additional research are being conducted to determine what method would be most effective in remediating the site. Since the bioslurry technique was unable to remediate test samples to the targeted clean-up level of 6.1 ppm, a higher performance goal of 40-60 ppm has been proposed and may be established. The additional research on the site began summer 1994 and should be complete by fall 1994.

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V	Newark Air Force Base** Newark, OH UST Lead (State)	Vincent Power (614)522-7077 Federal (or national) organization	Vadose soil (gasoline, TPHs) Volume: 60 cubic yards	Full-scale bioremediation is not planned. Pilot-scale studies were completed 12/93. Started 08/92. Incurred costs: capital, $35K; O&M, $1,000. Total expected costs: capital, $35K; O&M, $2,000.	Vadose soil: TPHs, 642 mg/kg; gasoline, 360 mg/kg (risk-based).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	The remediation involves small, localized areas of petroleum product contamination; therefore, the treatability study may accomplish complete remediation of the site. Most of the areas were below the state's action levels initially. Informal policies placed the TPH standard at an arbitrary 100 mg/kg; very infeasible and subject to false positives and organic interference. By targeting small, localized areas, bioventing could accomplish remediation to the risk-based levels enacted shortly after reporting this site. In addition, facility upgrade projects would remove residual contamination.
V	Onalaska Municipal Landfill** LaCrosse County, WI CERCLA Fund Lead	Kevin Adler (312)886-7078 Federal (or national) organization Paul Kozol (608)264-6013 State (or provincial) organization Steve Keith (414)272-2426 Contractor/ engineering firm	Saturated soil (TCE) / vadose and saturated soil (BTEX, naphthalene, TPHs) Volume: 5,000 cubic yards	Full-scale remediation has been underway since 05/94. Expected completion 09/96. Laboratory-scale studies were completed 03/92. Total expected costs: capital, $400K; O&M, $20K.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Soils inside the landfill have yet to be addressed. Methane in the landfill might pose a problem.

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V	Organic Chemical** Grandville, MI CERCLA Fund Lead	Tom Williams (312)886-6157 Federal (or national) organization	Vadose soil (BTEX) / ground water (BTEX lube oil, TCE, toluene) Volume: 6,500,000 cubic feet	Laboratory-scale studies are planned.	Not yet established.	Bioremediation treatment not yet established. Nonbiological technologies: levels of organics are so high at the site that bioremediation is not practical until the levels are lowered. Ground water pump and treat with an air stripper and GAC is being used as an interim measure.	Review of dioxin data has revealed that soil will be handled by EPA in Cincinnati. Site is waiting for the feasibility study to do remediation on the TCE and toluene and is working on an additional plan for oil. Ground water pump and treat began in December 1993.
V	Rasmussen Livingston County, MI CERCLA Enforcement Lead	Ken Glatz (312)886-1434 Federal (or national) organization Leslie Smith III (517)335-3386 State (or provincial) organization	Ground water (2-butanone, 4-methyl-2-pentanone, acetone)	Predesign.	Ground water: acetone, 700 ppb; 2-butanone, 350 ppb; 4-methyl-2-pentanone, 350 ppb.	Ex situ treatment, fixed film. Exogenous organisms. Nonbiological technologies: chemical treatment, air stripping/carbon adsorption with nutrient addition.	None.
V	Reilly Tar** Indianapolis, IN CERCLA Enforcement Lead	Dion Novak (312)886-4737 Federal (or national) organization Krista Eskilson (317)243-5088 State (or provincial) organization	Ground water (benzene, ammonia, pyridine) Volume: 7,000,000 gallons per day	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been underway since 01/89. Total expected cost: $15M.	Not yet established.	Ex situ treatment, sequencing batch reactor, completely mixed flow. Nonbiological technologies: chemical extraction.	Site consists of 60 to 80 ft of aquifer with conductivities of 0.01 to 0.001 with interfingering until units are not continuous (clay); 7,000,000 gallons per day are planned to be pumped from lower zone aquifier. The total amount of ground water to be treated has not yet been determined. A record of decision has only been written for the ground water IRM (proposed cost $15M); other portions of the site are still in the feasibility studies stage, and bioremediation is under consideration.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
V	Reilly Tar & Chemical Company** St. Louis Park, MN CERCLA Enforcement Lead	Daryl Owens (312)886-7089 Federal (or national) organization Douglas Beckwith (612)296-7715 State (or provincial) organization Jim McArthur (612)296-7297 State (or provincial) organization	Vadose soil (2-fluorobiphenyl, acenaphthylene, acenaphthene, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, BAP, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, PAHs, phenanthrene, pyrene) Volume: 2,000 cubic yards	Full-scale remediation is planned. Pilot-scale studies have been underway since 11/92. Expected completion 11/95. Incurred cost: $25K. Total expected cost: $70K.	Not yet established.	In situ treatment, bioventing. Nutrient addition. Aerobic conditions, indigenous organisms.	None.
V	Saginaw Bay Confined Disposal Facility** Bay City, MI Federal Facility Process 1	Frank Snitz (313)226-6748 Federal (or national) organization Jim Galloway (313)226-6760 Federal (or national) organization	Sediments (PCBs) Volume: 6 tons	Full-scale bioremediation is not planned. Pilot-scale studies are planned. Expected completion 04/96. Incurred cost: capital, $3,000. Total expected costs: capital, $3,000; O&M, $15K. Costs per year: O&M, $5,000.	Not established.	In situ treatment, periodic tilling. Aerobic and anaerobic conditions, indigenous organisms. Nonbiological technologies: soil washing.	Contaminated fines from a hydrocyclone washing process will be disposed of in a 30-ft diameter tank located on a structure that is permitted to receive contaminated dredged material. The fines will be tilled periodically. The effects of weather on PCB degradation also will be monitored.
	Process 2		Sediments (PCBs) Volume: 6 tons	Full-scale bioremediation is not planned. Pilot-scale studies are planned. Expected completion 04/96. Incurred cost: capital, $3,000. Total expected costs: capital, $3,000; O&M, $15K. Costs per year: O&M, $5,000.	Not established.	In situ treatment, devegetation. Aerobic and anaerobic conditions, indigenous organisms. Nonbiological technologies: soil washing.	Contaminated fines from a hydrocyclone washing process will be disposed of in a 30-ft diameter tank located on a structure that is permitted to receive contaminated dredged material. The fines will undergo a devegetation process. The effects of weather on PCB degradation also will be monitored.

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	Process 3		Sediments (PCBs) Volume: 6 tons	Full-scale bioremediation is not planned. Pilot-scale studies are planned. Expected completion 04/96. Incurred cost: capital, $3,000. Total expected costs: capital, $3,000; O&M, $15K. Costs per year: O&M, $5,000.	Not established.	In situ treatment, no active remediation. Aerobic and anaerobic conditions, indigenous organisms.	Contaminated fines from a hydrocyclone washing process will be placed in a 30-ft diameter tank located on a structure that is permitted to receive contaminated dredged material. The effects of weather on PCB concentrations will be monitored, but no action will be taken to stimulate PCB degradation.
V	Seymour Recycling** Seymour, IN CERCLA Enforcement Lead	Jeff Gore (312)886-6552 Federal (or national) organization Prabhakar Kasarabada (317)243-5130 State (or provincial) organization	Soil (DCE, TCE, vinyl chloride) / ground water (TCE, benzene, chloroethane, DCE, vinyl chloride) Volume of ground water: 500,000 gallons Volume of soil: 111,000 cubic yards	Full-scale remediation was completed 09/90. Incurred costs: capital, $900K; O&M, $100K.	Ground water: drinking water standards.	In situ treatment, in situ ground water bioremediation, in situ soil bioremediation (in situ land treatment). Nutrient addition (potassium, nitrogen, phosphorous, sulfur). Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction, multi-layer cap.	Since a multi-layer cap was applied over the bio-applied soil, there is no way to sample the contaminated soil. The RI in 1984 found more than 54 organic chemicals. It was difficult to landfarm nutrients below the surface as far as we would have preferred.
V	Sheboygan River and Harbor** Sheboygan, WI CERCLA Enforcement Lead Process 1	Bonnie Eleder (312)886-4855 Federal (or national) organization Jane Lemcke (608)264-0544 State (or provincial) organization Rick Fox (312)886-7979 Federal (or national) organization	Sediments (PCBs) Volume: 2,500 cubic yards	Full-scale bioremediation is not planned. Laboratory-scale and pilot-scale studies have been completed.	Not established.	Ex situ treatment, confined treatment facility (tank). Aerobic and anaerobic conditions, indigenous organisms. Nonbiological technologies: armoring (capping) pilot-scale study was undertaken on armoring effects on biodegradation, solidification/stabilization, thermal extraction, chemical dechlorination, solvent extraction.	Delays in pilot-scale study due to additional laboratory-scale tests and coordination with ARCS Program as Pilot Demonstration Project for Sheboygan AOC. Effectiveness and reliability are unproven. Process takes a long time. TSCA requirements: might not be able to achieve a 2 ppm treatment level.
	Process 2			Predesign.	Not yet established.	In situ treatment, in situ sediment bioremediation.	Several rounds of samples have been collected but results are inconclusive.

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V	Sleeping Bear Dunes National Lakeshore Empire, MI Federal Facility	John Wilson (405)332-8800 Federal (or national) organization Guy Sewell (405)332-8800 Federal (or national) organization	Ground water (petroleum) Volume: 1,000 gallons	Predesign.	Not yet established.	Anaerobic conditions, indigenous organisms.	Site had an excess of isomers.
V	Speigelberg Landfill Livingston Township, MI CERCLA Enforcement Lead	Ken Glatz (312)886-1434 Federal (or national) organization Leslie Smith III (517)335-3386 State (or provincial) organization	Ground water (2-butanone, hexanone)	Predesign.	Ground water: 2-butanone, 350 ppb; hexanone, 50 ppb.	Exogenous organisms. Nonbiological technologies: air stripping/carbon adsorption with nutrient addition.	None.
V	St. Louis River Interlake/Duluth Tar Site** Duluth, MN CERCLA State Lead	Ann Bidwell (612)296-7827 State (or provincial) organization Debbie Siebers (312)353-9299 Federal (or national) organization John Betcher (612)296-7821 State (or provincial) organization	Soil (PAHs) Volume: 3,300 cubic yards	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies are being conducted. Total expected costs: capital, $88.8K; O&M, $172K.	Soil: carcinogenic PAHs, 0.08 mg/kg (risk-based).	In situ treatment, bioventing, in situ soil bioremediation (in situ land treatment). Ex situ land treatment. Nutrient addition (nutrients undetermined at this point). Aerobic conditions, indigenous organisms. Nonbiological technologies: thermal desorption, "pure tar" found in isolated "tar seeps" at the site will be thermally destroyed as fuel.	Remedy for PAH-contaminated soils has not been selected. The final RI reports for the soils operable unit currently is being reviewed along with Alternatives Screening Projects.
V	Union Carbide—Marietta Facility** Marietta, OH CERCLA Enforcement Lead Process 1	Kevin Turner (312)886-4444 Federal (or national) organization Jessica Smith (614)385-8501 State (or provincial) organization	Soil (dioxin, dichlorinated biphenyls, monochlorinated biphenyls, PCBs, VOCs) / ground water (dioxin, dichlorinated biphenyls, benzene, chlorobenzene, monochlorinated biphenyls, PCBs, phenol, VOCs)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies were completed 07/93.	Not yet established.	Ex situ treatment, activated sludge, completely mixed flow. Aerobic and anaerobic conditions, exogenous and indigenous organisms.	A treatability study has been completed. Site is in proposed plan/ROD stage.
	Process 2		Ground water (benzene, chlorobenzene, phenol)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies were completed 07/93.	Ground water: MCLs (not yet determined).	Ex situ treatment, fluidized bed, completely mixed flow. Aerobic and anaerobic conditions, exogenous and indigenous organisms. Nonbiological technologies: GAC.	A treatability study has been completed. Site is in proposed plan/ROD stage.

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	Process 3		Ground water (benzene, chlorobenzene, phenol)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies were completed 07/93.	Ground water: MCLs (not yet determined).	Ex situ treatment, aerated lagoon.	A treatability study has been completed. Site is in proposed plan/ROD stage.
	Process 4		Ground water (benzene, chlorobenzene, phenol)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies were completed 07/93.	Ground water: MCLs (not yet determined).	In situ treatment, in situ ground water bioremediation. Oxygen source, nutrient addition.	A treatability study has been completed. Site is in proposed plan/ROD stage.
	Process 5		Ground water (benzene, chlorobenzene, phenol)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies were completed 07/93.	Ground water: MCLs (not yet determined).	In situ treatment, trickling filters.	A treatability study has been completed. Site is in proposed plan/ROD stage.
V	Upjohn Company Portage Facility** Kalamazoo, MI RCRA Lead (State)	Lorna Jereza (312)353-5110 Federal (or national) organization Peter Quackenbush (517)373-7397 State (or provincial) organization Greg Rudloff (312)335-3478 Federal (or national) organization	Soil / ground water (solvents)	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies have been underway since 01/87.	Not yet established.	Ex situ treatment, fixed film, non-aerated lagoon, completely mixed flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: in situ soil flushing, vacuum extraction.	Site anticipates possible problems with low winter temperatures.
V	Warner Lambert Company—Parke-Davis** Holland, MI RCRA Lead (Federal)	Shari Sutker (312)886-6151 Federal (or national) organization Dave Slayton (517)373-8012 State (or provincial) organization	Soil / ground water (petroleum, solvents)	Laboratory-scale and pilot-scale studies are planned.	Not yet established.	Ex situ treatment, fixed film. Aerobic conditions. Nonbiological technologies: air stripping and steam stripping.	None.

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REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
V	West K&L Avenue Landfill** Kalamazoo, MI CERCLA Enforcement Lead Process 1	Dan Cozza (312)886-7252 Federal (or national) organization Rob Franks (517)335-9295 State (or provincial) organization	Ground water (acetone, benzene, 1,2-DCA, TCE, 1,1-DCA, ethylbenzene, toluene, trans-1,2-DCE, vinyl chloride, xylene)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale and pilot-scale studies are being conducted. Total expected cost: $16M.	Ground water: acetone, 700 ppb; benzene, 1 ppb; vinyl chloride, 0.02 ppb; 1,2-DCA, 0.4 ppb; xylene, 20 ppb; toluene, 40 ppb; trans-1,2-DCE, 100 ppb; ethylbenzene, 30 ppb; 1,1-DCA, 700 ppb.	Ex situ treatment, fixed film, batch flow. Aerobic conditions. Nonbiological technologies: precipitation of metals, a carbon filter for the vinyl chloride, and landfill capping.	Laboratory-scale microcosms and pilot-scale lysimeter systems are being used to assess the biodegradative capacity of the aquifer and landfill material. Potential problems include treatment of vinyl chloride and handling of water after treatment. Discharge to POTW would be possible only with the installation of 3 miles of sewer line, and no surface water discharge is possible, so treated ground water must be reinjected.
	Process 2		Ground water (1,1-DCA, 1,2-DCA, acetone, benzene, ethylbenzene, TCE, toluene, trans-1,2-DCE, vinyl chloride, xylene)	Full-scale remediation is planned. Expected start 12/98. Laboratory-scale studies are being conducted. Expected completion 09/94. Pilot-scale studies are planned. Expected completion 06/97.	Ground water: 1,1-DCA, 700 ppb; 1,2-DCA, 0.4 ppb; trans-1,2-DCE, 100 ppb; xylene, 20 ppb; acetone, 700 ppb; benzene, 1 ppb; ethylbenzene, 30 ppb; toluene, 40 ppb; vinyl chloride, 0.02 ppb.	In situ treatment, in situ ground water bioremediation. Aerobic and anaerobic conditions, indigenous organisms.	Regulatory obstacles - ROD for the site will need to be amended as will the consent decree and SOW if remedy changed based on bioremediation field study.
V	Wright-Patterson Air Force Base** Dayton, OH Federal Facility	John Wolfe (513)257-2201 Federal (or national) organization	Vadose soil (BTEX jet fuel) Volume: 7,500 cubic yards	Pilot-scale studies have been underway since 07/93.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	None.
VI	Atchinson - ATSS Santa Fe Lake** Santa Fe, NM CERCLA Enforcement Lead	Ky Nichols (214)655-6783 Federal (or national) organization Stuart Kent (505)827-0037 State (or provincial) organization David Clark (913)435-2210 Industry	Sediments (diesel) / soil (hydrocarbons) Volume: 28,000 cubic yards % of total vol. at site: 100%	Full-scale remediation has been underway since 07/92. Pilot-scale studies have been completed. Total expected cost: $10M.	Sediments: diesel, 1,000 mg/kg (state guideline (California)). Soil: hydrocarbons, 1,000 mg/kg (state guideline (California)).	In situ treatment, in situ soil bioremediation (in situ land treatment). Ex situ land treatment. Nutrient addition. Aerobic conditions, indigenous organisms.	There is a possible problem with high chloride content in soil and sludges.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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VI	Dow Chemical Company—Louisiana Division** Plaquemine, LA RCRA Lead (State)	Madeline Murphy (504)765-0585 State (or provincial) organization Jill McCullough (504)353-8493 Industry	Ground water (1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCA, chloroethane) Volume: 90,000 cubic yards	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 12/90. Pilot-scale studies were completed 12/92. Incurred costs: capital, $250K; O&M, $10K. Total expected cost: $260K.	Not established.	In situ treatment, in situ ground water bioremediation. Nutrient addition (acetate, glucose, or ethanol proposed). Anaerobic conditions, indigenous organisms. Nonbiological technologies: pump and treat.	Permeability of the contaminated zones is low, and the supply (injection) of nutrients is difficult. All bioactivity may occur at the well screen, thereby plugging the screen. Unable to move nutrients through the contaminated zones even after hydraulic fracturing.
VI	French Limited** Crosby, TX CERCLA Enforcement Lead	Judith Black (214)655-6739 Federal (or national) organization Louis Rogers (512)463-8188	Sediments / soil / sludge (BAP, benzene, PCBs, VOCs) / ground water (hazardous contaminants)	Predesign.	Sludge: BAP, 9 ppm; PCBs, 23 ppm; VOCs, 43 ppm; benzene, 14 ppm. Ground water: MCLs (risk-based).	In situ treatment, air sparging, pure oxygen dissolution system. Oxygen source, nutrient addition (for soil, water, and sediments). Aerobic conditions, indigenous organisms.	This is the first full-scale application of in situ, slurry-phase bioremediation to a Superfund site cleanup.
VI	Hudson Refining Company** Cushing, OK RCRA Lead (Federal)	Ronnie Crossland (214)655-6480 Federal (or national) organization Mike Hebert (214)655-8315 Federal (or national) organization	Vadose soil (BAP, benzo(a)anthracene, chrysene, total oil and grease, total PAHs) Volume: 145,000 cubic yards % of total vol. at site: 40%	Full-scale remediation has been underway since 01/86. Incurred cost: $1M.	Vadose soil: total PAHs, 15 mg/kg; BAP, 200 µg/kg; benzo(a)anthracene, 200 µg/kg; chrysene, 200 µg/kg; total oil and grease, 960 mg/kg.	In situ treatment, in situ soil bioremediation (in situ land treatment). Nutrient addition. Aerobic conditions, indigenous organisms. Nonbiological technologies: excavation of soils exhibiting oil and grease concentrations greater than 20,000 ppm.	Since the refinery has gone into bankruptcy, the state and continuance of bioremediation is uncertain.
VI	Kelly Air Force Base San Antonio, TX Federal Facility	Kenny Johnson (210)925-1812 Federal (or national) organization Mark Weeger (512)908-2361 State (or provincial) organization	Vadose soil (benzene, BTEX jet fuel, ethylbenzene, PCE, DCE, TCE, toluene, vinyl chloride, xylene)	Full-scale remediation has been underway since 02/93. Expected completion 09/94.	Not yet established.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Nonbiological technologies: pump and treat for ground water.	Bioventing is to be used only within S-4 area of Kelly AFB on soils with fuel-related contamination.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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VI	Matagora Island Air Force Range** Matagora Island, TX UST Lead (State)	Jack Otis (409)766-8161 Federal (or national) organization David Harvey (512)851-8484 State (or provincial) organization Brent McCallick (210)661-4251 Contractor/ engineering firm	Vadose soil (BTEX jet fuel, benzene, ethylbenzene, toluene, TPHs, xylene) Volume: 871 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 03/93. Incurred cost: capital, $77.9K.	Vadose soil: TPHs, 500 mg/kg; BTEX, 1,000 mg/kg; benzene, 0.5 mg/kg; toluene, 100 mg/kg; ethylbenzene, 70 mg/kg; xylene, 1,000 mg/kg.	Ex situ treatment, pile, addition of Pseudomonas microbial slurry. Aerobic conditions, exogenous organisms.	Bioremediation proved successful in cleaning up the site to below the necessary levels. The site is now in the process of being closed to further remedial action.
VI	North Cavalcade Street** Houston, TX CERCLA State Lead	Glenn Celerier, P.E. (214)655-8523 Federal (or national) organization Steve Chong, P.E. (512)239-2441 State (or provincial) organization Larry Wright, P.E. (214)655-6715 Federal (or national) organization	Vadose soil (benzene, PAHs) Volume: 10,000 cubic yards	Full-scale remediation is planned. Currently in design. Pilot-scale studies were completed 10/92. Started 06/92. Total expected cost: $4M.	Vadose soil: carcinogenic PAHs, 1 mg/kg (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms.	None.
VI	Old Inger** Darrow, LA CERCLA State Lead	Paul Sieminski (214)655-8503 Federal (or national) organization Tim Knight (504)765-0487 State (or provincial) organization	Sludge (hydrocarbons) / soil (petroleum) Volume: 100,000 cubic yards % of total vol. at site: 70%	Full-scale remediation is being conducted. Laboratory-scale studies have been completed. Pilot-scale studies were completed 11/86. Started 10/85. Incurred cost: $5.4M. Total expected cost: $12.5M.	Sludge: contaminant reduction from 76% to 4%. Soil: contaminant reduction from 76% to 4%.	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: granular activated carbon for water treatment.	No problems with bioremediation. Full-scale operations were delayed due to state lag time in procuring contractor.
VI	Sheridan Disposal Services** Hempstead, TX CERCLA Enforcement Lead	Gary Baumgarten (214)655-6749 Federal (or national) organization	Sludge / soil / surface water (benzene, ethylbenzene, PCBs, phenol, toluene) Volume: 40,000 cubic yards	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been completed. Pilot-scale studies were completed 12/91. Started 04/91. Total expected cost: $28M.	Sludge: PCBs, 50 ppm (PCB spill cleanup policy). Soil: PCBs, 50 mg/kg.	Ex situ treatment, slurry reactor, completely mixed flow. Aerobic conditions. Nonbiological technologies: stabilization of residues.	Pilot study was completed and the report finalized in August 1993. PCB levels are used as indicators of levels of other organics.

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VI	Texas Eastern Gas Pipeline** Saint Francisville, LA TSCA Lead (Federal)	Joan Blake (202)260-6236 Federal (or national) organization	Soil (PCBs)	Full-scale bioremediation is not planned. Laboratory-scale studies have been completed. Pilot-scale studies were completed 04/93.	Soil: performance-based.	Ex situ treatment, biotreatment of soil in a plastic liner. Aerobic conditions, exogenous and indigenous organisms.	This was a treatability study carried out by a contractor hired by Texas Eastern. The studies indicated that bioremediation failed to reduce PCB contamination to within the necessary levels. Bioremediation of PCBs was not demonstrated in the 2-year duration of the experiment. Although bioremediation was considered, it was rejected and the site was landfilled.
VII	Amoco Refinery** Sugar Creek, MO RCRA Lead (State) Process 1	Rob Morrison (314)751-3176 State (or provincial) organization Alan Hancock (913)551-7647 Federal (or national) organization	Soil (phenanthrene, pyrene, naphthalene, toluene, xylene)	Full-scale remediation has been underway since 06/94. Laboratory-scale and pilot-scale studies have been completed.	Not yet established.	Ex situ treatment, aerated lagoon, pile. Aerobic conditions, indigenous organisms. Nonbiological technologies: thermal desorption.	There have been material handling problems such as mixing sludge for uniformity and providing enough oxygen without cooling the pond below an effective temperature.
	Process 2		Soil (phenanthrene, pyrene, naphthalene, toluene, xylene)	Full-scale remediation has been underway since 01/91.	Not yet established.	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: thermal desorption.	None.
VII	Conservation Chemical** Kansas City, MO CERCLA Enforcement Lead	Steve Auchterlonie (913)551-7778 Federal (or national) organization	Ground water (semivolatiles, phenols, VOCs) Volume: 200 gallons per minute % of total vol. at site: 100%	Full-scale remediation has been underway since 01/90. Laboratory-scale studies were completed 01/89. Incurred cost: capital, $110K. Cost per year: O&M, $25K.	Ground water: VOCs, 5 µg/L; phenols, 1 ppb (EPA or Missouri drinking water standards).	Ex situ treatment, fixed film, completely mixed flow. Aerobic conditions, exogenous organisms. Nonbiological technologies: carbon adsorption, lime precipitation, and sulfide precipitation in series.	None.
VII	Fairfield Coal & Gas** Fairfield, IA CERCLA Enforcement Lead	Bruce Morrison (913)551-7755 Federal (or national) organization Johanshir Golchin (515)281-8925 State (or provincial) organization	Saturated soil / ground water (benzene, ethylbenzene, PAHs, toluene, xylene)	Full-scale bioremediation is not planned. Laboratory-scale studies have been completed. Pilot-scale studies were completed 01/93. Started 12/91. Incurred cost: O&M, $150K. Total expected costs: capital, $300K; O&M, $150K. Costs per year: O&M, $150K.	Saturated soil: benzene, 241 mg/kg; PAHs, 500 mg/kg; carcinogenic PAHs, 100 mg/kg. Ground water: benzene, 1 ppb; carcinogenic PAHs, 200 ppt.	In situ treatment, in situ ground water bioremediation, injection and extraction wells. Hydrogen peroxide, nutrient addition (water, (nitrate)). Aerobic conditions, indigenous organisms.	Future problems due to poor transmissivity of the aquifer are possible. Hydrogeologic conditions were determined to be prohibitive to bioremediation. Pilot study confirmed this.

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REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
VII	International Paper** Joplin, MO RCRA Lead (State)	Jim Tucholski (314)751-3176 State (or provincial) organization Rob Morrison (314)751-3176 State (or provincial) organization	Soil (creosote, PAHs, PCP) Volume: 100,000 cubic yards	Full-scale remediation has been underway since 05/94. Laboratory-scale studies were completed 01/90. Started 01/88. Total expected cost: $9M.	Soil: risk-based and state-required.	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: chemical treatment, soil washing proposed but restricted by land disposal restrictions.	Bioremediation initially failed at this site due to lack of temperature and moisture control; the units were flooded, blocking oxygen transfer. Basins were covered (10+ acres under each of four roofs) to control moisture and temperature, and bioremediation has started up again. Unable at this time to say whether this has worked. Land disposal restrictions limit cleanup options.
VII	Offutt Air Force Base** Bellevue, NE Federal Facility Process 1	Philip Cork (402)294-7621 Federal (or national) organization Ed Louis (402)471-4230 State (or provincial) organization Frank Werner (402)294-7621 Federal (or national) organization	Vadose soil (benzene, ethylbenzene, TPHs, xylene) Volume: 11,000 cubic yards % of total vol. at site: 55%	Full-scale remediation has been underway since 10/93. Expected completion 10/95. Pilot-scale studies have been underway since 08/92.	Vadose soil: benzene, 10 mg/kg; ethylbenzene, 10 mg/kg; xylene, 10 mg/kg; TPHs, 10 mg/kg (risk-based).	In situ treatment, bioventing. Oxygen source. Aerobic conditions, indigenous organisms.	Problems encountered with bioventing: high water table due to rains, blower motor failure.
	Process 2		Ground water (VOCs) Volume: 5,600,000 cubic feet	Full-scale remediation is planned. Laboratory-scale studies have been completed. Pilot-scale studies are planned. Expected completion 08/95. Total expected cost: $2.5M.	Ground water: risk-based.	In situ treatment, in situ ground water bioremediation. Hydrogen peroxide. Aerobic conditions, indigenous organisms.	Getting hydrogen peroxide to all parts of shallow aquifer being treated.
VII	Park City** Park City, KS RCRA Lead (State)	John Wilson (405)436-8532 Federal (or national) organization	Ground water (benzene, m-xylene, ethylbenzene, o-xylene, p-xylene, toluene) Volume: 22,000 cubic meters % of total vol. at site: 50%	Full-scale remediation has been underway since 06/93. Laboratory-scale studies were completed 01/93. Started 01/92. Incurred cost: $275K. Total expected cost: $650K.	Ground water: federal MCLs.	In situ treatment, in situ ground water bioremediation, in situ sediment bioremediation. Nutrient addition (nitrate is added as an electron receptor). Aerobic and anaerobic conditions, indigenous organisms.	Site is serving as a test case for new Kansas environmental regulations.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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VII	Scott Lumber** Alton, MO CERCLA Fund Lead	Bruce Morrison (913)236-3881 Federal (or national) organization	Vadose soil (acenaphthylene, fluorene, anthracene, benzo(b)fluoranthene, benzo(a)anthracene, BAP, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, PAHs, phenanthrene, pyrene) Volume: 15,900 tons % of total vol. at site: 90%	Full-scale remediation was completed 11/91. Started 06/90. Incurred costs: capital, $700K; O&M, $500K. Total expected cost: O&M, $600K. Cost per year: O&M, $300K.	Vadose soil: BAP, 14 mg/kg; PAHs, 500 mg/kg.	Ex situ land treatment. Aerobic conditions, indigenous organisms.	Health-based risk levels for PAHs were changing and inconsistent.
VII	Sioux City Pilot Study** Sioux City, IA CERCLA State Lead	Johanshir Golchin (515)281-8925 State (or provincial) organization	Soil (BTEX lube oil, PAHs) Volume: 100,000 cubic yards	Pilot-scale studies were completed 10/91. Started 08/91. Incurred cost: capital, $250K. Total expected cost: capital, $10M.	Soil: PAHs, 500 mg/kg; carcinogenic PAHs, 250 mg/kg.	Ex situ land treatment. Aerobic and anaerobic conditions, exogenous and indigenous organisms. Nonbiological technologies: chemical treatment.	Problems included high soil moisture, a large area of operation, low temperatures, and other climatic obstacles.
VII	Vogel Paint & Wax** Maurice, IA CERCLA State Lead	Jack Generaux (913)551-7690 State (or provincial) organization Bob Drustrup (515)281-8900 State (or provincial) organization	Soil (benzene, ethylbenzene, MEK, toluene, xylene) Volume: 40,000 cubic yards % of total vol. at site: 100%	Full-scale remediation has been underway since 10/91. Total expected cost: $2M.	Not yet established.	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: air stripping of ground water, product recovery.	Volatilization control/air monitoring are being evaluated.
VIII	Burlington Northern** Glendive, MT Water Quality Bureau Lead	Terry Webster (406)444-2406 State (or provincial) organization	Soil (diesel)	Full-scale remediation has been underway since 01/91.	Soil: diesel, 100 mg/kg (EPA Recommended Standard).	Ex situ land treatment, active tillage, nutrient control. Aerobic conditions, indigenous organisms.	None.
VIII	Burlington Northern Tie Plant** Somers, MT CERCLA Enforcement Lead	Jim Harris (406)449-5414 Federal (or national) organization Karen Zackheim (406)449-4067 State (or provincial) organization	Soil / ground water (PAHs) Volume: 60,000 cubic yards % of total vol. at site: 75%	Full-scale remediation has been underway since 09/93. Laboratory-scale studies have been completed. Total expected cost: $11M.	Soil: carcinogenic PAHs, 36 mg/kg (risk-based). Ground water: carcinogenic PAHs, 0.03 µg/L (water quality criteria).	In situ treatment, in situ ground water bioremediation, in situ soil bioremediation (in situ land treatment). Ex situ land treatment. Oxygen source, nutrient addition (nitrogen, phosphorus). Aerobic conditions, indigenous organisms. Nonbiological technologies: surface treatment of extracted ground water by carbon adsorption.	Pilot-scale field activities have been initiated because of low soil transmissivities. Onsite pumping tests were completed in the third quarter of FY1991. A portion of the site is adjacent to a large lake.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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VIII	Conoco Landfarm** Billings, MT RCRA Lead (State)	Mark Mohorcich (406)444-1430 State (or provincial) organization	Sludge (K048 organics, K048 metals, K051 metals, K051 organics) / soil (petroleum) Volume: 15 acres % of total vol. at site: 100%	Full-scale remediation has been underway since 01/73. Pilot-scale studies have been completed.	Sludge: K048 metals, 1,000 ppm; K051 metals, 1,000 ppm (closure performance standards).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: chemical adsorption, ion exchange, precipitation.	Conoco Billings Landfarm is seeking a No Migration Variance. The facility maintains a Montana Hazardous Waste Permit (MTHWP-88-02).
VIII	Exxon Landfarm** Billings, MT RCRA Lead (State)	Mark Mohorcich (406)444-1430 State (or provincial) organization	Sludge (K049 organics, K049 metals, K050 metals, K050 organics, K051 metals, K051 organics) Volume: 45,000 tons	Full-scale remediation has been underway since 01/80. Pilot-scale studies have been completed.	Sludge: K049 metals, 1,000 ppm; K050 metals, 1,000 ppm; K051 metals, 1,000 ppm (closure performance standard).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: chemical adsorption, ion exchange, precipitation.	Exxon Landfarm (Billings) has obtained a No Migration Variance. The facility maintains a Montana Hazardous Waste Permit (MTHWP-88-01).
VIII	Geraldine Airport** Geraldine, MT CERCLA State Lead	Amy Reynolds (406)443-5827 State (or provincial) organization	Vadose soil (2,4-D, aldrin, chlordane, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, β-BHC, dieldrin, endrin, toxaphene)	Full-scale bioremediation is not planned.	Not established.	Aerobic and anaerobic conditions, indigenous organisms.	No longer being considered due to failure of related pilot-scale treatability studies to substantially reduce pesticide levels.
VIII	Glasgow Former Air Force Base** Glasgow, MT Federal Facility	Steven Ott (402)221-7670 Federal (or national) organization Ben Mundie (406)444-5970 State (or provincial) organization Martin Rasmussen (402)221-3827 State (or provincial) organization	Vadose soil (BTEX, TPHs) Volume: 3,200 cubic yards	Full-scale remediation is planned. Expected start 07/95. Total expected costs: capital, $2,000; O&M, $1,000.	Vadose soil: TPHs, 100 mg/kg; BTEX, 10 mg/kg (DIRP standard).	Ex situ land treatment. Aerobic conditions, indigenous organisms.	The cold weather of northern Montana might pose an obstacle to effective landfarming. State is sensitive about the total volume of material to be landfarmed.
VIII	Hill Air Force Base** Salt Lake City, UT Federal Facility	Robert Stites (303)294-1974 Federal (or national) organization	Soil / ground water (TPHs)	Full-scale remediation has been underway since 09/91.	Not yet established.	In situ treatment, bioventing. Oxygen source. Aerobic conditions, indigenous organisms. Nonbiological technologies: vapor venting.	If Hill AFB can get funding, bioventing could be conducted on soils with different contaminant mixtures: (1) gasoline and chlorinated solvents, and (2) petroleum hydrocarbons, JP-4 jet fuel, dioxins/furans, and solvents.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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VIII	Idaho Pole Company** Bozeman, MT CERCLA State Lead Process 1	Jim Harris (406)449-5720 State (or provincial) organization Brian Antonioli (406)449-4067 State (or provincial) organization Janie Stiles ~~(406)449-4067~~ State (or provincial) organization	Vadose and saturated soil (fluoranthene, BAP, benzo(b)fluoranthene, anthracene, benzo(g,h,i)perylene, benzo(a)anthracene, benzo(k)fluoranthene, chrysene, indeno(1,2,3-cd)pyrene, PCP, phenanthrene, pyrene)	Full-scale remediation is planned. Currently in predesign. Total expected costs: capital, $900K; O&M, $130K.	Vadose/saturated soil: PCP, 48 mg/kg (risk-based).	Ex situ land treatment. Oxygen source, nutrient addition. Aerobic conditions, indigenous organisms.	None.
	Process 2		Sediments (fluoranthene, anthracene, BAP, benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, indeno(1,2,3-cd)pyrene, PCP, phenanthrene, pyrene)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies are planned. Expected start 07/95, expected completion 03/96. Pilot-scale studies are planned. Expected start 10/94, expected completion 03/96. Total expected costs: capital, $1.2M; O&M, $400K.	Sediments: PCP, 48 mg/kg (risk-based).	Ex situ treatment, fixed film, plug flow. Aerobic conditions, indigenous organisms.	None.
	Process 3		Ground water (2,4,6-trichlorophenol, fluoranthene, chrysene, benzo(b)fluoranthene, benzo(a)anthracene, anthracene, BAP, benzo(k)fluoranthene, fluorene, naphthalene, PCP, phenanthrene, pyrene)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies are planned. Expected start 07/95, expected completion 03/96. Pilot-scale studies are planned. Expected start 10/94, expected completion 03/96. Total expected costs: capital, $1.2M; O&M, $400K.	Ground water: PCP, 1 µg/L; pyrene, 0.4 µg/L; chrysene, 0.2 µg/L; benzo(b)fluoranthene, 0.2 µg/L; benzo(k)fluoranthene, 0.2 µg/L; benzo(a)anthracene, 0.1 µg/L; anthracene, 0.3 µg/L; BAP, 0.2 µg/L (MCL).	In situ treatment, in situ ground water bioremediation. Oxygen source, nutrient addition. Aerobic conditions, indigenous organisms.	None.
VIII	Joliet Weed Control District** Joliet, MT CERCLA State Lead	Amy Reynolds (406)443-5827 State (or provincial) organization	Vadose soil (2,4-D, dicamba, MCPA)	Full-scale bioremediation is not planned. Pilot-scale studies were completed 09/91.	Not established.	In situ treatment, in situ soil bioremediation (in situ land treatment). Aerobic and anaerobic conditions, indigenous organisms.	Pilot-scale study did not have adequate controls. No longer being considered due to high levels of dioxins and failure of related pilot-scale treatability studies to reduce pesticide levels substantially.

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VIII	Lake County Weed Control** Ronan, MT CERCLA State Lead	Amy Reynolds (406)443-5827 State (or provincial) organization	Vadose soil (2,4-D, atrazine, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, aldrin, β-BHC, γ-BHC, chlordane, dicamba, dieldrin, endrin, Far-go, methoxychlor, Tordon)	Full-scale bioremediation is not planned.	Not established.	Aerobic and anaerobic conditions, indigenous organisms.	No longer being considered due to natural degradation of pesticide levels to levels too low to perform pilot-scale study on and due to failure of related studies to substantially reduce pesticide levels.
VIII	Libby Ground Water Site** Libby, MT CERCLA Enforcement Lead Process 1	Jim Harris (406)449-5415 Federal (or national) organization	Ground water (PAHs, benzene, PCP) Volume: 10 gallons per minute	Full-scale remediation is being conducted. Laboratory-scale and pilot-scale studies have been completed.	Ground water: carcinogenic PAHs, 40 µg/L; noncarcinogenic PAHs, 400 µg/L; PCP, 1.05 mg/L; benzene, 5 mg/L.	Ex situ treatment, fixed film, bioreactor for ground water, plug flow. Aerobic conditions, indigenous organisms.	Oil-water separation in bioreactor has been a problem because free product has approximately the same specific gravity as water.
	Process 2		Soil (PAHs, PCP) Volume: 45,000 cubic yards % of total vol. at site: 100%	Full-scale remediation is being conducted. Pilot-scale studies have been completed.	Soil: carcinogenic PAHs, 88 mg/kg; PCP, 37 mg/kg.	Ex situ land treatment. Aerobic conditions, indigenous organisms.	Pyrene degradation rates in land treatment units for soils have been low, but pyrene has been removed from remediation requirements.
	Process 3		Ground water (benzene, PAHs, PCP) Volume: 10 gallons per minute	Full-scale remediation is being conducted. Laboratory-scale and pilot-scale studies have been completed.	Ground water: benzene, 5 mg/L; carcinogenic PAHs, 40 µg/L; noncarcinogenic PAHs, 400 µg/L; PCP, 1.05 mg/L.	In situ treatment, in situ ground water bioremediation. Oxygen source, nutrient addition (potassium, tripolyphosphate, ammonium chloride). Aerobic conditions, indigenous organisms.	None.
VIII	Miles City Airport** Miles City, MT CERCLA State Lead	Amy Reynolds (406)443-5827 State (or provincial) organization	Vadose soil (2,4-D, aldrin, chlordane, α-BHC, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, β-BHC, γ-BHC, atrazine, dieldrin, Far-go, methoxychlor, parathion-e, Tordon) / saturated soil (endrin)	Full-scale bioremediation is not planned.	Not established.	Aerobic and anaerobic conditions, indigenous organisms.	No longer being considered due to failure of related pilot-scale treatability studies to reduce pesticide levels substantially.
VIII	Montana Pole** Butte, MT CERCLA State Lead	Brian Antonioli (406)449-4067 State (or provincial) organization Sara Weinstock (406)449-5414 Federal (or national) organization	Sediments / ground water (PCP) / soil (PAHs, PCP) Volume: 200,000 cubic yards	Full-scale remediation is planned. Currently in predesign. Laboratory-scale and pilot-scale studies are planned. Expected start 05/95, expected completion 11/95. Total expected costs: capital, $3M; O&M, $12M. Costs per year: O&M, $1.2M.	Sediments: PCP, 34 mg/kg (risk-based). Soil: PCP, 34 mg/kg; PAHs, 4.2 mg/kg (risk-based). Ground water: PCP, 1 µg/L (MCL).	In situ treatment, in situ ground water bioremediation. Ex situ treatment, reactor type to be determined, land treatment. Hydrogen peroxide, oxygen source, nutrient addition (nutrients not yet determined). Aerobic conditions, indigenous organisms. Nonbiological technologies: in situ soil flushing.	The Montana Pole Site is in the pre-RD/RA stage and no remediation currently is taking place.

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VIII	Montana Rail Link—East Helena** East Helena, MT Water Quality Bureau	Terry Webster (406)444-2406 State (or provincial) organization	Soil (diesel)	Full-scale remediation has been underway since 05/92.	Soil: diesel, 100 mg/kg (EPA Recommended).	Ex situ land treatment, tillage, moisture and nutrient control. Aerobic conditions, indigenous organisms.	None.
VIII	Montana Rail Link—Missoula** Missoula, MT Water Quality Bureau	Terry Webster (406)444-2406 State (or provincial) organization	Soil (petroleum)	Full-scale remediation has been underway since 05/92.	Soil: petroleum, 100 mg/kg (EPA Recommended).	Ex situ land treatment, tillage, moisture and nutrient control. Aerobic conditions, indigenous organisms.	None.
VIII	Public Service Company** Denver, CO UST Lead (State) Process 1	Suzanne Stevenson (303)293-1669 State (or provincial) organization Lisa Weer (303)692-3451 State (or provincial) organization	Ground water (benzene, toluene, xylene) Volume: 12,000,000 gallons	Full-scale remediation was completed 03/92. Started 06/89. Incurred cost: $500K.	Ground water: risk-based.	In situ treatment, in situ ground water bioremediation, combined bioprocess. Hydrogen peroxide, nutrient addition (ammonium and phosphate compounds). Aerobic conditions, indigenous organisms. Nonbiological technologies: chemical treatment.	A risk assessment has been submitted to the State of Colorado Health Department for review. The State has accepted the closure application for the site.
	Process 2		Sediments (ethylbenzene, toluene, xylene)	Full-scale remediation has been completed.	Not supplied.	In situ treatment, bioventing, in situ ground water bioremediation, in situ sediment bioremediation. Oxygen source, nutrient addition. Aerobic conditions, indigenous organisms.	Higher costs than expected.
VIII	Richey Airport** Richey, MT CERCLA State Lead	Amy Reynolds (404)443-5827 State (or provincial) organization	Vadose soil (2,4-D, aldrin, dicamba, chlordane, α-BHC, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, β-BHC, γ-BHC, atrazine, dieldrin, endrin, Far-go, methoxychlor, parathion-e, parathion-m, Tordon) Volume: 15 gallons	Full-scale bioremediation is not planned. Laboratory-scale studies have been completed. Pilot-scale studies were completed 08/93. Started 01/93.	Not established.	Ex situ treatment, reactor (type not chosen). Aerobic and anaerobic conditions, indigenous organisms.	No longer being considered due to failure of the pilot-scale treatability studies to substantially reduce pesticide levels.
VIII	Union Pacific Railroad Tie Treatment Plant** Laramie, WY RCRA Lead (Federal)	Felix Flechas (303)293-1524 Federal (or national) organization	Soil / ground water (creosote, PAHs, PCP)	Full-scale bioremediation is not planned. Laboratory-scale and pilot-scale studies have been completed. Incurred cost: $35M. Total expected cost: $35M.	Not established.	In situ treatment, in situ ground water bioremediation, in situ sediment bioremediation, in situ soil bioremediation (in situ land treatment). Ex situ treatment, sequencing batch reactor, land treatment. Hydrogen peroxide, nutrient addition (N:P). Aerobic conditions, indigenous organisms. Nonbiological technologies: in situ soil flushing, soil washing.	Fluid delivery is not uniform, so bioremediation is not uniform. Cleanup of bedrock contamination is technically impracticable. Besides bedrock contamination, there are three considerations which lead to the conclusion that it is impracticable to bioremediate the area: (1) the size of the area, (2) the cost that would be incurred, and (3) the time required to bioremediate the area.

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IX	Aua Fuel Farm** American Samoa Federal Facility	Helene Takemoto (808)438-6931 Federal (or national) organization	Soil (diesel)	Full-scale remediation has been underway since 12/93. Expected completion 12/95. Pilot-scale studies were completed 01/92. Incurred costs: capital, $700K; O&M, $10K.	Soil: diesel, 50 mg/kg (risk-based).	In situ treatment, delivery of dissolved oxygen. Nutrient addition (soils (nitrogen, phosphorus)). Aerobic conditions, indigenous organisms.	Water pressure is an issue.
IX	Beale Air Force Base Marysville, CA Federal Facility Process 1	Sheri Rolfsness (916)634-2642 Federal (or national) organization	Vadose soil (diesel) Volume: 20,000 cubic yards % of total vol. at site: 100%	Full-scale remediation has been underway since 07/92. Pilot-scale studies were completed 12/91. Started 10/91. Incurred cost: capital, $30K. Total expected cost: O&M, $6,000.	Vadose soil: diesel, 50 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Pilot-scale test demonstrated that bioremediation could work in silty-clay soil.
	Process 2		Vadose soil (diesel, gasoline, solvents) Volume: 10,000 cubic yards	Pilot-scale studies have been underway since 10/92. Total expected costs: capital, $50K; O&M, $10K.	Vadose soil: gasoline, 10 mg/kg; diesel, 50 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Project will be a pilot-scale system, operating for one year.
	Process 3		Vadose soil (diesel, gasoline) Volume: 10,000 cubic yards	Pilot-scale studies have been underway since 10/92. Total expected costs: capital, $50K; O&M, $10K.	Vadose soil: diesel, 50 mg/kg; gasoline, 10 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Project will be a pilot-scale test for one year.
	Process 4		Vadose soil (diesel, gasoline) Volume: 3,000 cubic yards % of total vol. at site: 100%	Full-scale remediation has been underway since 11/92. Total expected costs: capital, $100K; O&M, $30K.	Vadose soil: gasoline, 10 mg/kg; diesel, 50 mg/kg (state guidelines).	Ex situ treatment, pile. Aerobic conditions, indigenous organisms.	Biofilters to treat contaminated soil were removed during Underground Storage Tank removal projects.
	Process 5		Vadose soil (benzene, diesel, ethylbenzene, toluene, xylene) Volume: 10,000 cubic yards	Pilot-scale studies have been underway since 10/92. Total expected costs: capital, $50K; O&M, $10K.	Vadose soil: diesel, 50 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Pilot-scale system to operate for one year.
	Process 6		Vadose soil (diesel, gasoline, TCE) Volume: 100,000 cubic yards	Full-scale remediation is planned. Currently in design. Remediation expected completion 06/96. Total expected costs: capital, $221K; O&M, $64K.	Vadose soil: diesel, 50 mg/kg; gasoline, 10 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	None.

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	Process 7		Vadose soil (benzene, diesel, ethylbenzene, toluene, xylene) Volume: 10,000 cubic yards	Full-scale remediation is planned. Currently in design. Remediation expected completion 10/96. Total expected costs: capital, $30K; O&M, $6,000.	Vadose soil: diesel, 50 mg/kg (state guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms.	Process area recently was discovered; little information is available.
IX	BKK Landfill West Covina, CA RCRA Lead (Federal)	Carmen Santos (415)744-2037 Federal (or national) organization Nancy Lindsay/Glenn Heyman (415)744-2044 Federal (or national) organization	Ground water (dichloromethane, carbon tetrachloride, chloroform, benzene, 1,2-dichloropropane, phenols, TCE, toluene, vinyl chloride) Volume: 50,000 gallons per day % of total vol. at site: 100%	Full-scale remediation has been underway since 01/87. Pilot-scale studies have been completed.	Not yet established.	Ex situ treatment, fluidized bed, completely mixed flow. Aerobic conditions. Nonbiological technologies: chemical treatment, may also treat landfill liquids to see if ground water not heavily contaminated can be stripped by an air stripping process.	A treatability study may be done on a mixture of landfill leachate and ground water to see if the system can treat it. Plant will be expanded. Air strippers, which exist but are not being used, might be used in the future.
IX	CALTRANS Lakeport, CA UST Lead (State)	Ken Smarkel (916)322-3910 State (or provincial) organization John Wesnousky (915)324-1807	Soil (hydrocarbons) Volume: 70 cubic yards	Full-scale remediation was completed 01/89. Started 11/88.	Soil: hydrocarbons, 100 mg/kg.	In situ treatment, in situ soil bioremediation (in situ land treatment). Nonbiological technologies: passive aeration.	Degradation rate was dependent upon the pile's porosity, water content, type of waste, soil, and bacterial consortium. Additional information on this site can be obtained through the California Department of Toxic Substances Control, Office of Pollution Prevention and Technology Development.
IX	Citrus Heights Irrigation Citrus Heights, CA UST Lead (State)	Ken Smarkel (916)322-3910 State (or provincial) organization John Wesnousky (916)324-1807	Soil (diesel) Volume: 120 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 08/89. Started 05/89.	Soil: diesel, 100 mg/kg.	Ex situ treatment, leachate recirculation, completely mixed flow. Aerobic conditions, indigenous organisms.	None.
IX	Converse/Montebello Corporation Yard** Montebello, CA UST Lead (State)	Paul Hadley (916)324-3823 State (or provincial) organization	Vadose soil (diesel, gasoline) Volume: 600 cubic yards	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been completed. Pilot-scale studies have been underway since 05/93.	Vadose soil: not available.	In situ treatment, bioventing, bioventing and bioremediation augmentation. Nutrient addition (soils (nitrate and phosphate)). Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction.	Results of pilot-scale will be considered when developing a full-scale system; the benefits of nutrient addition will be evaluated against bioventing without nutrient addition.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
IX	CWX Freight Lines** Santa Rosa, CA UST Lead (State)	Mark Berscheid (916)322-3294 State (or provincial) organization	Vadose soil (diesel) Volume: 600 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 11/91. Started 10/90. Pilot-scale studies have been completed.	Vadose soil: water board issue.	Ex situ land treatment. Nutrient addition (Solmar L-104, 32-10-10 fertilizer). Aerobic conditions, exogenous organisms.	None.
IX	Former Service Station** Los Angeles, CA UST Lead (State)	Tony Palagyi (206)774-6090 Industry	Soil (hydrocarbons) / ground water (benzene) Volume of vadose and saturated soil: 3,000 cubic yards % of total vol. at site: 65% Volume of ground water: 800,000 gallons	Full-scale remediation was completed 03/91. Started 11/88. Pilot-scale studies were completed 12/88. Started 01/88. Incurred cost: $1.6M.	Soil: hydrocarbons, 100 mg/kg (los Angeles County regulations). Ground water: benzene, 5 ppb (los Angeles County regulations).	In situ treatment, in situ ground water bioremediation, closed loop system. Hydrogen peroxide, nutrient addition (nitrogen and others). Aerobic conditions, indigenous organisms. Nonbiological technologies: in situ soil flushing, vacuum extraction.	During channeling, overload reduced the reinjection process rate.
IX	Fort Ord Army Base** Monterey, CA CERCLA Enforcement Lead	John Chesnutt (415)744-2387 Federal (or national) organization Gail Youngblood (408)242-8018 Federal (or national) organization	Vadose soil (diesel, gasoline, toluene, xylene) / ground water (1,2-DCE, TCE, TPHs) Volume: 4,000 cubic yards	Full-scale bioremediation is not planned. Pilot-scale studies were completed 05/94. Started 01/85.	Ground water: TPHs, 1,000 ppb; 1,2-DCE, 6 ppb; TCE, 5 ppb.	In situ treatment, in situ soil bioremediation (in situ land treatment). Nutrient addition (carbon fertilizers). Aerobic conditions, indigenous organisms. Nonbiological technologies: pump and treat, carbon adsorption.	Ground water was not the primary medium being treated but was used as part of the pump and treat system for the soil remediation. A large pilot-scale study was performed, and the treatment that was implemented was sufficient to remediate the site to within or below risk levels.
IX	Gila Indian Reservation** Bapchule, AZ CERCLA Fund Lead	Richard Martyn (415)744-2288 Federal (or national) organization	Soil (parathion, toxaphene) Volume: 80,000 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 07/86. Started 01/84. Incurred cost: $700K.	Soil: risk based.	In situ treatment, in situ soil bioremediation (in situ land treatment). Hydrogen peroxide, nutrient addition (alfalfa, manure). Aerobic and anaerobic conditions, indigenous organisms.	Toxaphene is very hard to break down. Materials handling was difficult.
IX	Growers Air Service Woodland, CA CRWQCB Lead	Christine Holm (916)255-3103 State (or provincial) organization	Soil (atrazine, Bravo, 1&2-DDT, dacthal, malathion, parathion, methyltrithion, ethion, parathion-m, paroxon, thiadine, thiadine sulfate, toxaphene, trifluralin, trithion)	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 10/88.	Not established.	Ex situ land treatment, lime addition. Anaerobic conditions.	The study was supposed to be on a pilot scale, but it ended up on a laboratory scale. The results were inconclusive due to many QA/QC problems in the analyses. The full-scale cleanup at this site has not begun. The Regional Board has not initiated action because of staff resource limitations. Future of bioremediation at this site is unclear.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
IX	Hamburg Ranch** Merced County, CA CERCLA State Lead	Christine Holm (916)255-3103 State (or provincial) organization Jack Grisanti (209)897-5873 Contractor/ engineering firm	Vadose and saturated soil (DDD, DDE, chlorfenvinphos, DDT, endosulfan, methidathion, Monitor, Nemacur, parathion-e, parathion-m, toxaphene)	Full-scale remediation is planned. Currently in predesign. Remediation expected completion 10/96.	Not yet established.	Bioremediation treatment not yet established.	This site is especially difficult because of the high degree of contamination and the amount of material involved. Excavation down to 1 ppm DDT, DDD, and DDE and 5 ppm toxaphene is now taking place. Much of this material will be disposed of at a Class 1 landfill, since it is characterized as non-RCRA waste. The remainder will be bioremediated on site. Bioremediation technology has not yet been selected. White rot fungus is a possibility.
IX	Harmon Field** Tulare County, CA CERCLA State Lead Process 1	Mike Pfister (209)297-3934 State (or provincial) organization	Vadose soil (DDT, toxaphene) Volume: 200 cubic yards	Full-scale remediation is planned. Pilot-scale studies are planned. Expected completion 12/94. Total expected cost: capital, $50K.	Vadose soil: toxaphene, 1 mg/kg; DDT, 1 mg/kg (risk-based).	Ex situ treatment, lined cells on aboveground containers, organic material and lime addition. Aerobic conditions, indigenous organisms. Nonbiological technologies: thermal desorption.	The project is still in its planning stages: proposed testing the effect of plant root activity on bioremediation; to test the activity, proposed growing rice, which requires that water be recirculated continuously, creating technical problems regarding the handling of water.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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	Process 2		Soil (α-BHC, chlordane, dicofol, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, endosulfan II, endrin, endrin aldehyde, heptachlor, heptachlor epoxide, methoxychlor, toxaphene) Volume: 65 gallons	Full-scale bioremediation is not planned. Pilot-scale studies were completed 11/90. Started 05/90. Incurred cost: capital, $120K. Total expected cost: capital, $120K.	Soil: chlordane, 1 mg/kg; dicofol, 1 mg/kg; endosulfan II, 1 mg/kg; endrin, 1 mg/kg; endrin aldehyde, 1 mg/kg; heptachlor epoxide, 1 mg/kg; 4,4'-DDE, 1 mg/kg; 4,4'-DDT, 1 mg/kg; 4,4'-DDD, 1 mg/kg; methoxychlor, 1 mg/kg; toxaphene, 1 mg/kg; heptachlor, 1.	Ex situ land treatment, lime and moisture addition. Aerobic and anaerobic conditions, exogenous and indigenous organisms. Nonbiological technologies: thermal desorption.	Tests were conducted on thirteen 5-gallon buckets of soil. Results showed that pesticides were not removed from the containers after 192 days of treatment. Due to the high variability of the data, however, it is unclear whether some degradation occurred. A larger scale study may be conducted to achieve statistically significant results. Results of this testing were inconclusive regarding the effectiveness of the bioremediation process in remediating the site.
IX	Hercules Incorporated** Hercules, CA CERCLA State Lead	Mehdi Sunga (510)540-3825 State (or provincial) organization	Soil (DNT, nitrobenzene, TNT) Volume: 1,500 cubic yards	Full-scale bioremediation is not planned. Pilot-scale studies were completed 01/91. Started 01/89.	Soil: TNT, 30 mg/kg; DNT, 5 mg/kg; nitrobenzene, 5 mg/kg.	Ex situ land treatment. Aerobic conditions, indigenous organisms.	The pilot-scale studies were very promising, and cleanup levels were achieved fairly quickly. However, the timing for full-scale bioremediation was not favorable. There were other technical problems. Only landfarming was tried, no slurry type bioremediation.
IX	J.H. Baxter** Weed, CA CERCLA Enforcement Lead Process 1	Kathy Setian (415)744-2254 Federal (or national) organization Susan Warner (707)576-2220 Municipal (or local) organization Ed Cargile (916)255-3703 State (or provincial) organization	Sediments (tetrachlorophenol) / soil (PAHs, PCP) Volume: 21,875 cubic yards	Full-scale remediation is planned. Currently in predesign. Expected start 12/94. Laboratory-scale and pilot-scale studies have been completed. Total expected costs: capital, $9.6M; O&M, $3.3M; total, $13M.	Sediments: tetrachlorophenol, 1 mg/kg (risk-based). Soil: PCP, 17 mg/kg; carcinogenic PAHs, 0.51 mg/kg; noncarcinogenic PAHs, 0.15 mg/L (risk-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: cement fixation for soils contaminated with inorganics.	None.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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	Process 2		Ground water (PAHs, dioxins, PCP) Volume: 150,000 gallons per day	Full-scale remediation is planned. Currently in predesign. Expected start 12/94. Pilot-scale studies have been underway since 01/89. Total expected costs: capital, $4.3M; O&M, $13.1M; total, $17.4M.	Ground water: carcinogenic PAHs, 5 µg/L; noncarcinogenic PAHs, 5 µg/L; PCP, 2.2 µg/L; dioxins, 0.025 ppt (risk-based).	Ex situ treatment, fixed film, completely mixed flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: chemical treatment.	There is some concern regarding the effect of elevated metals on bioremediation process.
IX	JASCO Mountain View, CA CERCLA Enforcement Lead	Rose Marie Caraway (415)744-2356 Federal (or national) organization	Soil (1,1-DCA, 1,1,1-TCA, 1,1-DCE, 1,2-DCE, acetone, benzene, chloroethane, MEK, diesel, ethylbenzene, methanol, methylene chloride, PCE, PCP, TCE, toluene, vinyl chloride, xylenes) / ground water (acetone, 1,1-DCA, 1,1-DCE, 1,2-DCA, benzene, methylene chloride, PCE, PCP, toluene, TPHs, vinyl chloride) Volume: 1,100 cubic yards	Full-scale remediation is planned. Currently in design. Laboratory-scale studies were completed 11/91. Started 02/91. Incurred cost: $30K. Total expected costs: capital, $200K; O&M, $248K.	Soil: 1,1-DCA, 0.03 mg/kg; 1,1-DCE, 1 mg/kg; 1,1-DCA, 0.6 mg/kg; 1,2-DCE, 1 mg/kg; 1,1,1-TCA, 100 mg/kg; benzene, 0.3 mg/kg; chloroethane, 4,000 mg/kg; MEK, 9 mg/kg; acetone, 30 mg/kg; methylene chloride, 0.2 mg/kg; PCP, 200 mg/kg; PCE, 7 mg/kg; TCE, 3 mg/kg; toluene, 1,000 mg/kg; vinyl chloride, 0.02 mg/kg; methanol, 200 mg/kg; xylenes, 2,000 mg/kg; diesel, 10K mg/kg; ethylbenzene, 3,000 mg/kg (potential migration to ground water). Ground water: acetone, 4,000 ppb; benzene, 1 ppb; 1,1-DCA, 5 ppb; 1,1-DCE, 6 ppb; 1,2-DCA, 0.5 ppb; methylene chloride, 150 ppb; PCP, 1 ppb; toluene, 1 ppb; vinyl chloride, 0.5 ppb; TPHs, 3,000 ppb; PCE, 5 ppb.	Ex situ treatment, ex situ reactor treatment, batch flow. Aerobic and anaerobic conditions.	The ROD selected an ex situ bioremediation process, which will combine aerobic and anaerobic treatments. The challenges at this site are (1) to minimize volatilization of contaminants during excavation, and (2) to balance the aerobic and anaerobic processes to treat the entire contaminated area. If cleanup levels are not achieved, contaminated material will be disposed of in a RCRA landfill.
IX	Koppers Company, Inc. Oroville, CA CERCLA Enforcement Lead	Fred Schauffler (415)744-2359 Federal (or national) organization Ed Cargile (916)255-3703 State (or provincial) organization	Vadose soil (PAHs, dioxins, furans, PCP) Volume: 110,000 cubic yards	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies were completed 01/93. Pilot-scale studies are planned. Expected completion 11/94. Total expected costs: capital, $4.5M; O&M, $7.7M.	Vadose soil: PCP, 17 mg/kg; carcinogenic PAHs, 0.19 mg/kg; dioxins, 0.03 ppt; furans, 0.03 ppt.	In situ treatment, in situ soil bioremediation (in situ land treatment). Nutrient addition. Aerobic conditions, indigenous organisms. Nonbiological technologies: soil washing, fixation of metal-contaminated soil, ground water treatment with carbon.	None.
IX	MCAGCC Twenty-Nine Palms** Twenty-Nine Palms, CA DOD section of Superfund: Defense Environmental Restoration Account Process 1	Cristopher Kyberg (619)532-1998 Federal (or national) organization Ray Lukens (619)776-8958 State (or provincial) organization	Soil (gasoline, JP-5)	Full-scale remediation is planned. Currently in design. Pilot-scale studies have been underway since 01/94. Expected completion 01/97.	Soil: JP-5, 1,000 mg/kg.	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Nonbiological technologies: some of the bioventing sites are irrigated with water.	There have been problems with acceptance of bioremediation technology.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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	Process 2		Soil (gasoline, JP-5 jet fuel) Volume: 1,800,000 cubic yards	Pilot-scale studies have been underway since 01/94.	Soil: JP-5 jet fuel, 1,000 mg/kg.	In situ treatment, in situ natural aspiration of wells. Aerobic conditions, indigenous organisms.	None.
IX	Middle Mountain Silvex** Greenlee County, AZ Federal Facility	Robert M. Mandel (415)744-2290 Federal (or national) organization Tim Steele (602)257-2335 State (or provincial) organization	Vadose soil (2,4,5-T, 2,4-D) Volume: 550 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 09/92. Incurred cost: $19.5K.	Vadose soil: 2,4,5-T, 50 mg/kg (state requirement).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Prepared bed with water and nutrients; periodic rototilling. Nonbiological technologies: photodegradation by ultraviolet sunlight at elevation of 9,000 ft above sea level.	None.
IX	Montrose Chemical Corporation of California** Torrance, CA CERCLA Enforcement Lead	Nancy Woo (415)744-2404 Federal (or national) organization Gloria Conti (310)590-5566 State (or provincial) organization Steven Safferman (513)569-7350 Federal (or national) organization	Vadose soil (DDT)	Full-scale bioremediation is not planned. Laboratory-scale studies were completed 03/94. Started 09/92.	Not established.	Ex situ land treatment. Aerobic conditions, exogenous organisms.	Inoculated fungus had trouble competing with indigenous population and did not significantly reduce DDT concentrations. Laboratory-scale studies indicated that land treatment was not an effective method of remediating the site. Test results failed to meet the proposed cleanup levels. No further bioremediation is planned, and the soil will either be capped or be taken off site for incineration.
IX	Moore Aviation** Colusa, CA CERCLA State Lead	Christine Holm (916)255-3103 State (or provincial) organization Bruce Locken (916)753-9500 Contractor/ engineering firm	Vadose soil (DDE, chlorpyrifos, disulfoton, 2,4-D, 2,4,5-T, atrazine, endosulfan I, endosulfan II, parathion, propazine) Volume: 75 cubic yards	Full-scale remediation has been underway since 09/91. Laboratory-scale studies were completed 01/90. Pilot-scale studies have been completed. Total expected cost: $35K.	Vadose soil: DDE, 1 mg/kg; endosulfan I, 7.4 mg/kg; parathion, 3 mg/kg; chlorpyrifos, 2 mg/kg; disulfoton, 0.1 mg/kg; propazine, 0.14 mg/kg; atrazine, 0.03 mg/kg; 2,4-D, 1 mg/kg; 2,4,5-T, 0.1 mg/kg; endosulfan II, 7.4 mg/kg (beneficial use water quality criteria).	Ex situ land treatment. Aerobic and anaerobic conditions, indigenous organisms.	There are some problems with QA/QC on analyses; two independent labs are giving conflicting results. Endosulfans have been particularly recalcitrant. This has not allowed the project to come to a full completion, in part due to the fact that the cleanup levels are somewhat stringent.

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FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

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IX	Naval Air Station—Fallon** Fallon, NV Federal Facility	Ron Hoeppel (805)982-1655 Federal (or national) organization David Chesmore (702)687-5872 State (or provincial) organization Doug Bonham (702)426-2772 Naval Base Environmental Coordinator	Vadose soil / saturated soil (benzene, ethylbenzene, toluene, xylene) / vadose and saturated soil (JP-5 jet fuel) / ground water (JP-5 jet fuel, ethylbenzene, 1-methylnaphthalene, benzene, n-butylbenzene, naphthalene, p-xylene, toluene) Volume: 20,000 cubic yards	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been underway since 09/93. Expected completion 09/95. Pilot-scale studies have been underway since 01/93. Expected completion 06/96. Incurred costs: capital, $250K; O&M, $500K. Total expected costs: capital, $250K; O&M, $250K.	Vadose/saturated soil: risk-based.	In situ treatment, bioslurping. Oxygen source. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction, vacuum enhanced free fuel recovery (provided by vacuum extraction bioventing techniques).	Site has had problems obtaining a water discharge permit from the State of Nevada to discharge treated ground water to the NAS Fallon sewer system due to presence of natural arsenic in ground water. Excessive free fuel in contaminated zones appears to be impeding biodegradation. Once excess fuel is removed, biodegradation rates are expected to increase.
IX	Naval Weapons Station—Seal Beach** Seal Beach, CA Federal facility (state priority list site)	Carmen LeBron (805)982-1616 Federal (or national) organization	Ground water (BTEX)	Full-scale remediation is planned. Currently in predesign. Laboratory-scale studies have been completed. Pilot-scale studies have been underway since 12/92. Expected completion 12/95.	Not yet established.	In situ treatment, in situ ground water bioremediation. Nutrient addition. Aerobic and anaerobic conditions, indigenous organisms.	Benzene is most recalcitrant, however, only after 100 days acclimation period does it degrade.
IX	Oakland Chinatown Oakland, CA UST Lead (State)	Donald Smallbeck (415)883-0112 Contractor/ engineering firm	Soil / ground water (BTEX, TPHs) Volume: 10,000 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 08/90. Started 03/89. Laboratory-scale studies were completed 01/89. Started 10/88. Incurred costs: capital, $300K; O&M, $480K. Total expected cost: O&M, $1.2M. Cost per year: O&M, $720K.	Soil: BTEX, 50 µg/kg; TPHs, 100 mg/kg (RWQCB guidelines). Ground water: BTEX, 1 µg/L (MCL).	In situ treatment, in situ ground water bioremediation, in situ soil bioremediation (in situ land treatment). Ex situ treatment, completely mixed reactor. Hydrogen peroxide, nutrient addition (soils and water (ammonia nitrate, mono- and di-basic phosphates)), completely mixed flow. Aerobic conditions, indigenous organisms. Nonbiological technologies: carbon adsorption.	Site has been closed since 1990 and a plaza has been built in its place.
IX	Poly-Carb** Wells, NV CERCLA Fund Lead	Robert M. Mandel (415)744-2290 Federal (or national) organization	Soil (cresol, phenols) Volume: 1,500 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 09/88. Started 06/87. Laboratory-scale studies were completed 05/87. Started 03/87. Incurred cost: $450K. Total expected cost: $600K.	Soil: cresol, 10 mg/kg; phenols, 20 mg/kg (performance-based).	Ex situ land treatment. Aerobic conditions, indigenous organisms. Nonbiological technologies: in situ soil flushing; in situ volatilization.	None.

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IX	Protek Carson City, CA UST Lead (State)	Ken Smarkel (916)322-3910 State (or provincial) organization	Soil (TPHs) Volume: 700 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 12/89. Started 08/88.	Soil: TPHs, 10 mg/kg.	Ex situ land treatment.	The control cell, which did not receive any nutrient supplements, proprietary inoculum, or the benefit of rigorous aeration, showed contaminant level reductions equal to those of the treatment cells. Additional information on this site can be obtained through the California Department of Toxic Substances Control, Office of Pollution and Prevention and Technology Development.
IX	San Diego Gas and Electric** San Diego, CA UST Lead (Federal)	Paul Hadley (916)324-3823 Federal (or national) organization	Soil (BTEX) Volume: 600 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 04/93. Started 10/89. Incurred cost: capital, $25K. Cost per year: O&M, $12.5K.	Not supplied.	In situ treatment, in situ ground water bioremediation, in situ soil bioremediation (in situ land treatment). Nutrient addition (NO3, PO4, K+). Anaerobic conditions, indigenous organisms.	None.
IX	Seaside High School Seaside, CA UST Lead (State)	Dick Ericksson (916)322-7046 State (or provincial) organization	Soil (diesel) Volume: 100 cubic yards % of total vol. at site: 100%	Full-scale remediation was completed 06/88.	Soil: diesel, 500 mg/kg.	Ex situ land treatment. Aerobic conditions, indigenous organisms.	Diesel-contaminated soil was remediated and placed as a road base material prior to paving.
IX	SEGS Solar Project** Kramer Junction, CA State Lead	Bruce LaBelle (916)324-2958 State (or provincial) organization	Soil (biphenyl, diphenyl ether)	Full-scale remediation has been underway since 07/90. Laboratory-scale studies have been completed. Pilot-scale studies were completed 01/90.	Soil: biphenyl, 1,000 mg/kg; diphenyl ether, 1,000 mg/kg (risk-based).	Ex situ treatment, pile. Aerobic conditions, indigenous organisms.	Full-scale treatment is used on an ongoing basis for treatment of soil contaminated by occasional leaks and spills.
IX	Solvent Service** San Jose, CA CERCLA State Lead	Tony Mancini (510)286-0825 State (or provincial) organization Marie Lacey (415)744-2234 Federal (or national) organization	Ground water (1,2-DCE, cis-1,2-DCE, 1,1,1-TCA, acetone, 1,1-DCE, benzene, ethylbenzene, freon 113, naphthalene, trans-1,2-DCE)	Full-scale remediation has been underway since 01/91. Incurred cost: $399K. Total expected cost: $844K.	Ground water: 1,2-DCE, 5 µg/L; cis-1,2-DCE, 6 µg/L; trans-1,2-DCE, 10 µg/L; ethylbenzene, 400 µg/L; 1,1,1-TCA, 200 µg/L; freon 113, 1,200 µg/L; benzene, 0.7 µg/L; acetone, 400 µg/L; 1,1-DCE, 1 µg/L; naphthalene, 2,000 µg/L (not yet established).	Ex situ treatment, fixed film, completely mixed flow. Anaerobic conditions, exogenous organisms. Nonbiological technologies: vacuum extraction, air stripper with carbon absorption unit.	Site had difficulty obtaining a permit for bioremediation.

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IX	Southern Pacific Transportation Company Roseville, CA CERCLA State Lead	David Wright (916)332-3910 State (or provincial) organization	Soil (hydrocarbons) Volume: 240 tons	Full-scale remediation was completed 01/91. Started 11/90. Incurred cost: $310K.	Soil: hydrocarbons, 5,000 mg/kg.	Ex situ land treatment.	None.
X	East 15th Street Service Station** Anchorage, AK UST Lead (State)	Tony Palagyi (206)774-6090 Industry	Soil (diesel) Volume: 1,500 cubic yards % of total vol. at site: 20%	Full-scale remediation has been underway since 06/92. Pilot-scale studies have been underway since 02/94. Expected completion 12/94. Incurred cost: $75K. Total expected cost: $200K.	Soil: diesel, 100 mg/kg (regulatory guidelines).	In situ treatment, bioventing. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction.	Winter weather has been an obstacle to bioremediation.
X	Fairchild Air Force Base** Spokane, WA Federal Facility Process 1	2nd Lt. Todd Luce (509)247-5170 Federal (or national) organization William Harris (206)438-3070 Diane Wulf (509)247-2313 Federal (or national) organization	Vadose soil (BTEX, TPHs) Volume: 700 cubic yards	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies have been underway since 03/94. Expected completion 03/95. Total expected costs: capital, $50K; O&M, $2,000.	Vadose soil: TPHs, 200 mg/kg (state standard).	In situ treatment, bioventing. Oxygen source. Aerobic conditions, indigenous organisms.	None.
	Process 2		Vadose soil (BTEX, TPHs) Volume: 700 cubic yards	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies have been underway since 03/94. Expected completion 03/95. Total expected costs: capital, $50K; O&M, $2,000.	Vadose soil: TPHs, 200 mg/kg (state standard).	In situ treatment, bioventing. Oxygen source. Aerobic conditions, indigenous organisms.	None.
	Process 3		Vadose soil (BTEX, TPHs) Volume: 700 cubic yards	Full-scale bioremediation is not planned. Pilot-scale studies have been underway since 03/94. Expected completion 03/95. Total expected costs: capital, $50K; O&M, $2,000.	Vadose soil: TPHs, 200 mg/kg (state standard).	In situ treatment, bioventing. Oxygen source. Aerobic conditions, indigenous organisms.	Pilot-scale studies will be sufficient to remediate the contaminated area.

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	Process 4		Vadose soil (benzene, TPHs) Volume: 700 cubic yards	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies have been underway since 03/94. Expected completion 03/95. Total expected costs: capital, $20K; O&M, $2,000.	Vadose soil: benzene, 0.5 mg/kg (state standard).	In situ treatment, bioventing. Oxygen source. Aerobic conditions, indigenous organisms.	None.
	Process 5		Vadose soil (BTEX, TPHs) Volume: 700 cubic yards	Full-scale bioremediation is not planned. Pilot-scale studies have been underway since 03/94. Expected completion 03/95. Total expected costs: capital, $20K; O&M, $2,000.	Vadose soil: TPHs, 200 mg/kg; BTEX, 200 mg/kg (state standard).	In situ treatment, bioventing. Oxygen source. Aerobic conditions, indigenous organisms.	Pilot-scale studies will be sufficient to remediate the site.
	Process 6		Vadose soil (benzene) Volume: 1,000 cubic yards	Full-scale remediation is planned. Currently in predesign. Pilot-scale studies have been underway since 07/94. Expected completion 06/95. Total expected costs: capital, $50K; O&M, $5,000.	Vadose soil: benzene, 0.5 mg/kg (state standard).	In situ treatment, air sparging, bioventing. Oxygen source. Aerobic conditions, indigenous organisms.	None.
X	J.H. Baxter Company** Renton, WA State Lead	Gail Colburn (206)649-7058 State (or provincial) organization Ching-Pi Wang (206)649-7134 State (or provincial) organization	Sediments / sludge / vadose and saturated soil / ground water (PAHs, PCP, TPHs) Volume: 20,000 cubic yards	Full-scale remediation is planned. Currently in design. Remediation expected completion 10/98. Laboratory-scale studies were completed 11/92. Started 08/92.	Vadose/saturated soil: risk-based. Ground water: risk-based.	Ex situ land treatment. Aerobic conditions, exogenous and indigenous organisms.	This site may not be able to meet RCRA treatability standards for land disposal. Benzo(a)pyrene appears to be the most difficult compound to degrade. Other results are very good: 40 percent to 90 percent removals on individual PAHs. Those bins experiencing drainage problems had reduced rates of bioremediation. Properly draining bins showed 90 percent reductions.
X	Texas Tower** Fort Greely, AK Federal Facility	Paul Laverty (907)753-5719 Federal (or national) organization	Vadose soil / ground water (diesel) Volume: 3,000 cubic yards	Predesign.	Vadose soil: diesel, 100 mg/kg (state regulation). Ground water: diesel, 0.005 mg/L (MCL for benzene).	In situ treatment, air sparging. Oxygen source. Aerobic conditions, indigenous organisms. Nonbiological technologies: vacuum extraction.	None.

*Indicates a new site.
**Indicates that contacts have provided updated information for this bulletin.

Shading indicates a non-CERCLA site.

FIELD APPLICATIONS OF BIOREMEDIATION (cont.)

REG	SITE/ LOCATION/ LEAD	CONTACT/ PHONE NUMBER	MEDIA/ CONTAMINANT/ VOLUME	STATUS/ COSTS	TARGET CLEANUP LEVELS	TREATMENT SUMMARY	COMMENTS
X	Utah Power and Light** Idaho Falls, ID RCRA Lead (State)	Judith Myers (208)334-5898 State (or provincial) organization Randy Steger (208)334-5898 State (or provincial) organization	Vadose soil (PAHs)	Full-scale bioremediation is not planned. Pilot-scale studies were completed 07/91.	Vadose soil: PAHs, 50 µg/kg (permit standards).	In situ treatment, in situ soil bioremediation (in situ land treatment). Aerobic conditions, exogenous organisms. Nonbiological technologies: pump and treat.	Addition of water or mixing and drying were not monitored. There were no indications of dilution or volatilization. Tests were determined to be unsuccessful.
X	Wyckoff Eagle Harbor** Puget Sound, WA CERCLA Enforcement Lead	Rene Fuentes (206)553-1599 Federal (or national) organization Peter Rubenstein (206)553-1067 Federal (or national) organization	Ground water (PAHs, PCP) Volume: 60 gallons per minute	Full-scale bioremediation is not planned.	Ground water: PCP, 6 µg/L; PAHs, 20 µg/L (water quality criteria).	Ex situ treatment, physical separation of wastes and water with activated carbon addition. Attached growth process in series with aeration tank, clarifier, and biological sludge digester. Aerobic conditions. Nonbiological technologies: pump and treat for water, floating and sinking oil extraction and separation.	Site has lower TOC than expected during design and periodically experiences problems with PCP toxicity. Additional research and planning is being conducted on the site. The original treatment facility is in need of repair or replacement so that any further plans for remediation have been put on hold.

GLOSSARY OF BIOREMEDIATION TERMS

Growth Conditions

Aerobic-In the presence of oxygen.

Anaerobic-In the absence of oxygen.

Source of Microorganisms

Indigenous-Occurring naturally at a site.

Exogenous-Not native to a site.

Treatment in a Reactor

Activated Sludge-The biomass is suspended in liquid, captured in a clarifier, and recycled to the reactor; the contact time between the waste and the biomass is controlled by wasting excess biomass.

Extended Aeration-The biomass is suspended in liquid, captured in the clarifier, and recycled to the reactor; a long contact time is created by enlarging the aeration basin.

Contact Stabilization-The waste contacts the biomass suspended in liquid in the first aeration tank and contaminants are adsorbed to the clarified biomass; then they are digested in the second aeration tank.

Fixed Film-Biomass is retained in the system by using a static support media.

Fluidized Bed-Bacteria is attached to a support media, which is fluidized in the reactor.

Sequencing Batch Reactor-This self-contained treatment system incorporates equalization, aeration, and clarification using a draw and fill approach on wastewater sludges.

Slurry Reactor-Contaminants are treated in a soil slurry (a thin mixture of soil and water) with nutrients and oxygen added as needed; water and soil must be separated after treatment, but clean soil is left on site.

Treatment Outside of a Reactor

Aerated Lagoon-The biomass is kept suspended in liquid with aeration.

Land Treatment-Waste is applied onto or incorporated into the soil surface in a facility. Contaminants are treated with microorganisms typically indigenous to the existing soil matrix; nutrients, moisture, and oxygen can be added to optimize growth conditions. If the waste remains at the facility after closure, the land treatment facility becomes a disposal facility.

Pile-This method refers to any noncontainerized accumulation of solid, nonflowing waste being treated or stored.

Bioventing-Air is injected into contaminated soil at rates low enough to increase soil oxygen concentrations and stimulate indigenous microbial activity without releasing volatile emissions.

In Situ Treatment-Biodegradable contaminants are treated by microorganisms within the environment in which they are found. Most commonly, this process utilizes aerobic processes and involves delivery of oxygen or other electron acceptors and other appropriate amendments.

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